PB85-233518

Survey of Perchloroethylene Emission Sources

(U.S.) Environmental Protection Agency
Research Triangle Park, NC

Jun 85

U.S. Department of Commerce
National Technical Information Service
NTIS

PB85-233518

United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park NC 27711

EPA-450/3-85-017
June 1985

Air

EPA

Survey of Perchloroethylene Emission Sources

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TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA 4507/3-85-017	2.	3. RECIPIENT'S ACCESSION NO. PB85 233518/AS
4. TITLE AND SUBTITLE Survey of Perchloroethylene Emission Sources		5. REPORT DATE June 1985 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Office of Air Quality Planning and Standards Environmental Protection Agency Research Triangle Park, North Carolina 27711		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO. EPA Contract 68-02-3816
12. SPONSORING AGENCY NAME AND ADDRESS DAA for Air Quality Planning and Standards Office of Air and Radiation U.S. Environmental Protection Agency Research Triangle Park, North Carolina 27711		13. TYPE OF REPORT AND PERIOD COVERED Final 14. SPONSORING AGENCY CODE EPA/200/04
15. SUPPLEMENTARY NOTES		

16. ABSTRACT

The potential health impact of perchloroethylene emissions is being investigated. This document contains information on the sources of perchloroethylene emissions, current emission levels, and State regulations applicable to the emission sources.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution Pollution Control Synthetic Organic Chemical Manufacturing Industry Perchloroethylene Tetrachloroethylene	Air Pollution Control	13B

18. DISTRIBUTION STATEMENT Unlimited	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 133
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

EPA-450/3-85-017

Survey of Perchloroethylene Emission Sources

Emission Standards and Engineering Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

June 1985

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1.0 INTRODUCTION AND SUMMARY

1.1 INTRODUCTION

This document identifies the sources and locations of perchloroethylene (PCE) emissions, estimates total production volumes and emission levels, and identifies the applicable control technologies for each source. The information collected in this source assessment study will also be used by the U. S. Environmental Protection Agency (EPA) to estimate human exposure to PCE.

Information for this document was acquired from various sources. The approach to information gathering for each of these sources is discussed in the following paragraphs.

Background information, such as previous EPA documents and other published literature was reviewed in an attempt to identify the producers of PCE and the major uses and applications. Five companies producing PCE at eight facilities were identified. Two chlorofluorocarbon (CFC) producers using PCE as an intermediate were also identified. Letters were sent to these seven companies under the authority of Section 114 of the Clean Air Act requesting information concerning PCE emissions, emission levels, and control techniques from all possible emission sources associated with the production, storage, and use of PCE in the calendar year 1983. General production information such as production volumes and total sales/purchase data were also requested in order to verify the completeness of the information. These data are considered confidential information by the companies and are not discussed in this report. For each process unit making or consuming PCE, detailed information was requested on the following emission types: fugitive emissions, process vent emissions, equipment opening losses, raw material/product storage emissions, loading/handling emissions, and secondary emissions. The companies were asked only to estimate these emissions. No testing was required to be done specifically for this information request.

Plant trips were taken to Vulcan Chemicals in Geismar, Louisiana, and Dow Chemical U. S. A. in Plaquemine, Louisiana, to gain familiarity with the processes, emission sources, and emissions controls at these PCE production facilities. Meetings were held with plant representatives to discuss operating procedures, the process equipment used, potential emission sources, and methods of emissions control.

The other major uses of PCE were identified to be dry cleaning and solvent degreasing. Since there are numerous facilities using PCE in these applications, no attempt was made to obtain any direct information from these facilities. However, information was obtained from the Halogenated Solvents Industrial Alliance (HSIA), a trade group representing the producers of PCE and other chlorinated solvents, about the total amounts of PCE used in 1983 for various applications.[1] Using this and other available information, 1983 emissions were estimated for each application.

1.2 SUMMARY

1.2.1 PCE Emission Source Categories

PCE is produced by eight chemical companies at eleven plants in the United States. Five of these companies produce PCE at eight facilities as a main product. Three other companies produce PCE as a by-product at three other facilities. The estimated total 1983 production volume of PCE was 249,200 megagrams (Mg).[1] Three different processes are used to produce PCE. In 1983, 51 percent of the PCE produced was consumed by the dry cleaning industry, 25 percent was used as an intermediate in the production of CFC's, 15 percent was used as a solvent in degreasing operations, and 9 percent was used in miscellaneous applications.[1] The miscellaneous applications include the production of adhesives, aerosols, and paints and coatings. The consumption of PCE has declined by about 30 percent since 1980,[2] causing some former PCE producers to halt production of the chemical.

Emission estimates have been made in this study for the following categories: PCE production, CFC production, miscellaneous production (PCE as a by-product), dry cleaning, degreasing operations, distribution sources, miscellaneous uses, and publicly-owned treatment works (POTWs).

1.2.2 Emission Estimates

The total emissions from PCE production and use in 1983 were 106,000 Mg/yr. The largest sources of emissions were dry cleaning facilities (50,000 Mg/yr), degreasing operations (32,600 Mg/yr), and PCE production facilities (650 Mg/yr). The emission sources and emissions are shown in Table 1-1.

PCE emissions from production processes are estimated to be 650 Mg/yr. This estimate was obtained from the information provided by the plants in response to Section 114 requests. This information included emission estimates from process vents (estimated at full plant capacity), loading/handling operations, equipment opening losses, pressure relief valve discharges, and secondary streams. The plants also provided equipment counts for fugitive emission sources in PCE service and data on the number and types of product/raw material storage tanks containing PCE. Total volatile organic compound (VOC) emissions from fugitive emission sources were calculated by applying Synthetic Organic Chemical Manufacturing Industry (SOCMI) VOC fugitive emission factors to the equipment count.[2] PCE emissions were estimated by applying the fraction of PCE in the stream for each piece of equipment to the calculated VOC emissions. (Actual test data were provided by one plant for PCE fugitive emissions.) Emissions from storage tanks were estimated by using AP-42 equations.[3] Methods for estimating these emissions are described in Appendix A.

It is estimated that in 1978, there were approximately 11,804 coin-operated, 15,060 commercial, and 334 industrial dry-cleaning facilities in the United States using PCE. No attempt was made in this study to update the estimated number of dry cleaning facilities. The amounts of PCE consumed by the three sectors of the dry cleaning industry in 1983 were obtained from HSIA.[1] Based on the consumption data and the emission factors for each of the three sectors of the industry (obtained from previous EPA documents), it is estimated that about 50,000 Mg of PCE was emitted from dry cleaning facilities in 1983.

TABLE 1-1. EMISSIONS FROM THF PRODUCTION AND USE OF PERCHLOROETHYLENE

Process	Production/Consumption (Mg/yr)	Emissions (Mg/yr)
PCE Production	230,400	650
CFC Production	60,300	34
Misc. Production	N/A	245
Dry Cleaning	117,000	50,000
Degreasing	35,000	32,600
Distribution	162,000[a]	50
MISCELLANEOUS USES		
• Adhesives	2,800	2,800
• Aerosols	2,530	2,500
• Paints & Coatings	1,660	1,600
• Miscellaneous	13,700	13,700
POTWs	-	2,000
TOTAL		106,000

N/A = Not available

[a] Amount of PCE estimated to be sold through distributors.

Information was also obtained from HSIA on the 1983 consumption of PCE in degreasing applications.[1] The HSIA indicated that PCE was used as a degreasing solvent in five major industry groups in 1983. These are: furniture and fixtures (Standard Industrial Classification (SIC) 25), fabricated metal products (SIC 34), electric and electronic equipment (SIC 36), transportation equipment (SIC 37), and miscellaneous industries (SIC 39). Emission factors for degreasing operations were obtained from previous EPA studies and total 1983 emissions of PCE from degreasing facilities were estimated from 1983 consumption data. It is estimated that degreasing accounted for 32,600 Mg of PCE emissions in 1983.

Miscellaneous uses of PCE include use in manufacture of adhesives, aerosols, and paints and coatings. Essentially all PCE used in these consumer product applications are emitted to the atmosphere. It is estimated that approximately 21,000 Mg of PCE were emitted from these miscellaneous uses.

Almost all of the PCE produced is sold through various chemical distributors. The handling and storage operations at distribution facilities located throughout the country were estimated to emit 50 Mg of PCE emissions in 1983. Finally, information from previous EPA studies indicate that about 2,000 Mg of PCE is emitted from POTWs annually.

1.2.3 Regulatory Requirements

The 14 plants that produce PCE or use it as an intermediate are located in five States: Texas, California, Louisiana, Michigan, and Kansas. VOC emissions from these existing production facilities are not controlled by Federal regulations such as the new source performance standards (NSPS) for volatile organic compounds in the synthetic organic chemicals manufacturing industry. However, two plants that produce PCE as a by-product may be controlled by the national emission standards for hazardous air pollutants (NESHAP) for vinyl chloride (VC). In addition, the emissions at most plants are controlled to some extent in each of these States by county, district, or State regulations.

California is currently the only State with regulations for fugitive emissions control. In the Bay Area Air Quality District of California, where the Dow Chemical U. S. A., Pittsburg facility is located, organic compounds with vapor pressures less than 1.5 pounds per square inch absolute (psia) are exempt from control by the regulation for fugitive emissions from valves and flanges (Regulation 8, Rule 22). Since the vapor pressure of PCE is 0.3 psia, this facility is not covered by this regulation. On January 20, 1984, Louisiana initiated a fugitive emissions control program. The regulations will require a VOC leak patrol/repair program, and full compliance will be required by December 31, 1987. The Texas Air Control Board (TACB) has recently promulgated regulations that will require a formal fugitive emissions monitoring program in Texas. The first round of monitoring must be completed by the end of 1987.

PCE emissions from process vents are not controlled in any of these states. Regulations exist in Texas for process emissions, but PCE is exempt due to the vapor pressure cutoff limit of 0.44 psia. If the stream also contains VOC with vapor pressures greater than 0.44 psia, the total stream vapor pressure must be evaluated prior to ruling for an exemption.

VOC emissions from storage tanks are regulated in California, Texas, Louisiana, and Michigan. Kansas only regulates emissions from storage tanks containing petroleum. In the Bay Area Air Quality District of California, PCE emissions from storage tanks are exempt from control due to a vapor pressure cutoff of 1.5 psia. In general, a storage tank with a capacity greater than 151,400 liters (40,000 gallons) but storing liquid with less than 76 kilopascals (kPa) (11 psia) vapor pressure, would require a floating roof with seals between the tank wall and roof edge, or a vapor recovery system which returns vapor to a disposal system. For tanks smaller than 151,400 liters (40,000 gallons), use of a submerged fill pipe during loading is considered sufficient control, and for tanks larger than 151,400 liters (40,000 gallons) storing liquids with a vapor pressure greater than 76 kPa (11 psia), a submerged fill pipe and vapor recovery system is required.

VOC emissions from loading/handling operations are controlled in Louisiana, Texas, and Michigan. However, Louisiana is the only one of these States in which PCE emissions are not exempt from control due to a vapor pressure cutoff of 1.5 psia. Loading facilities for VOC with throughputs of at least 75,700 liters (20,000 gallons/day) (40,000 gallons or more for existing facilities) must be equipped with vapor collection and disposal systems. Barges and ships are exempt from loading/handling regulations. There are no regulations for VOC emissions from loading/handling in Kansas or the Bay Area Air Quality District in California.

There are no Federal regulations for PCE emissions from dry cleaners. Control Techniques Guideline (CTG) documents have been issued by EPA establishing reasonably available control technology (RACT) guidelines that have been used by State agencies to develop State implementation plans (SIPs). Twenty-three States have adopted RACT for PCE dry cleaning. Twenty-six States have not adopted any regulations. The decision to adopt RACT provisions is pending in New York.

There are no Federal regulations for PCE emissions from degreasing operations. A CTG for organic solvent cleaners has been issued by EPA establishing RACT guidelines that have been used by State agencies to develop SIPs. Thirty-two States plus the District of Columbia have adopted RACT for the use of PCE in degreasing operations. Eighteen States have not adopted any regulations. Further details on State regulations are contained in Appendix B.

1.3 REFERENCES

1. Letter from D. L. Morgan, Cleary, Gottlieb, Steen, and Hamilton, to R. E. Rosensteel, EPA/ESED. March 1, 1985. Response for Halogenated Solvents Industrial Alliance concerning industial consumptions volumes of PCE in 1983.

2. Mannsville Chemical Products. Chemical Products Synopsis - Perchloroethylene. Cortland, New York. November 1984.

3. Compilation of Air Pollutant Emission Factors, 3rd edition. U. S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Monitoring and Data Analysis Division. Research Triangle Park, NC. January 1984.

4. Letter and attachments from Komorski, K. S., PPG, to Farmer, J. R., EPA/ESED. February 14, 1985. Response to PCE 114 letter.

2.0 PERCHLOROETHYLENE PRODUCTION

This chapter presents the emissions and controls associated with the production of PCE at the eight production facilities in the United States. Two of these facilities use the PCE product for additional chemical processing within the plant. Three other plants also produce PCE as a by-product in the production of VC, trichloroethylene (TCE), and carbon tetrachloride (CCl_4).[1] Emissions from PCE production facilities come from process vents, equipment leaks, storage tanks, secondary sources, and truck, railcar or barge loading.

PCE is currently produced by three processes. These are the chlorination of ethylene dichloride (EDC), hydrocarbon chlorinolysis, and the oxychlorination of EDC.[2]

2.1 QUANTITIES PRODUCED AND MANUFACTURERS

PCE is currently produced by five companies at eight facilities. The estimated total production capacity of these plants is about 410,500 Mg/yr.[2] In 1983, about 230,400 Mg/yr of PCE was produced.[2] The total imports of PCE in 1983 were 24,950 Mg/yr, and the total exports were 24,490 Mg/yr.[2] The producers, their capacities, and production process are listed in Table 2-1. The types and amounts of emissions from these facilities are shown in Table 2-2. The plant locations are shown in Figure 2-1.

Several companies, such as Stauffer Chemical Company (Louisville, KY), Ethyl Corporation (Baton Rouge, LA) and Occidental Petroleum Company (Taft, LA) have stopped producing PCE due to the decline in PCE consumption in recent years.[2] Dow Chemical U.S.A. has recently stopped producing PCE at its Freeport, TX facility. The United States' capacity for PCE will be further reduced when duPont converts its plant in Corpus Christi, TX to chloroform and CCl_4 production by the end of 1985.[2]

TABLE 2-1. PERCHLOROETHYLENE PRODUCTION FACILITIES

Company	Location	Process	Capacity[a] (Mg/yr) (1984)
Diamond Shamrock Corporation	Deer Park, TX	Chlorination of Ethylene Dichloride	74,844
Dow Chemical U.S.A.	Freeport, TX	Chlorination of Ethylene Dichloride	68,000[b]
	Plaquemine, LA	Chlorinolysis	40,824
	Pittsburg, CA	Chlorinolysis	22,680
E.I. duPont de Nemours & Company, Inc.	Corpus Christi, TX	Chlorinolysis	72,570
PPG Industries, Inc.	Lake Charles, LA	Oxychlorination of Ethylene Dichloride	108,864
Vulcan Materials Company	Geismar, LA	Chlorinolysis	68,040
	Wichita, KS	Chlorinolysis	22,680

[a] Estimated capacities from Mannsville Chemical Products Corporation.

[b] Dow Chemical stopped production of perchloroethylene and carbon tetrachloride at the Freeport facility in 1984.

TABLE 2-2. TOTAL EMISSIONS FROM PERCHLOROETHYLENE PRODUCTION FACILITIES

	1983 Perchloroethylene Emissions (Mg/yr)							
Plant/Location	Process	Fugitive[a]	Relief Devices	Storage[b]	Handling	Equipment Openings	Secondary	Total (Mg/yr)
Diamond Shamrock Deer Park, TX	9.0	138.4	-	75.0	3.8	-	-	226.2
Dow Chemical U.S.A. Freeport, TX	19.5	80.4	-	15.4	0.07	0.2	0.12	115.7
Vulcan Chemicals Geismar, LA	2.2	60.0	-	23.0	-	0.004	-	85.2
Vulcan Chemicals Wichita, KS	-	40.1	-	15.8	0.7	0.8	-	57.4
Dow Chemical U.S.A. Pittsburg, CA	-	0.41	-	13.8	1.13	0.34	-	15.7
Dow Chemical U.S.A. Plaquemine, LA	8.2	55.8	-	21.4	3.65	2.2	0.52	91.7
E.I. duPont de Nemours Corpus Christi, TX	0.21	13.6	-	0.97	-	0.09	-	14.9
PPG Industries Lake Charles, LA	0.2	23.5	0.2	18.5	1.3	0.4	-	44.1
TOTAL	39.3	412.2	0.2	183.9	10.6	4.0	0.64	650.9

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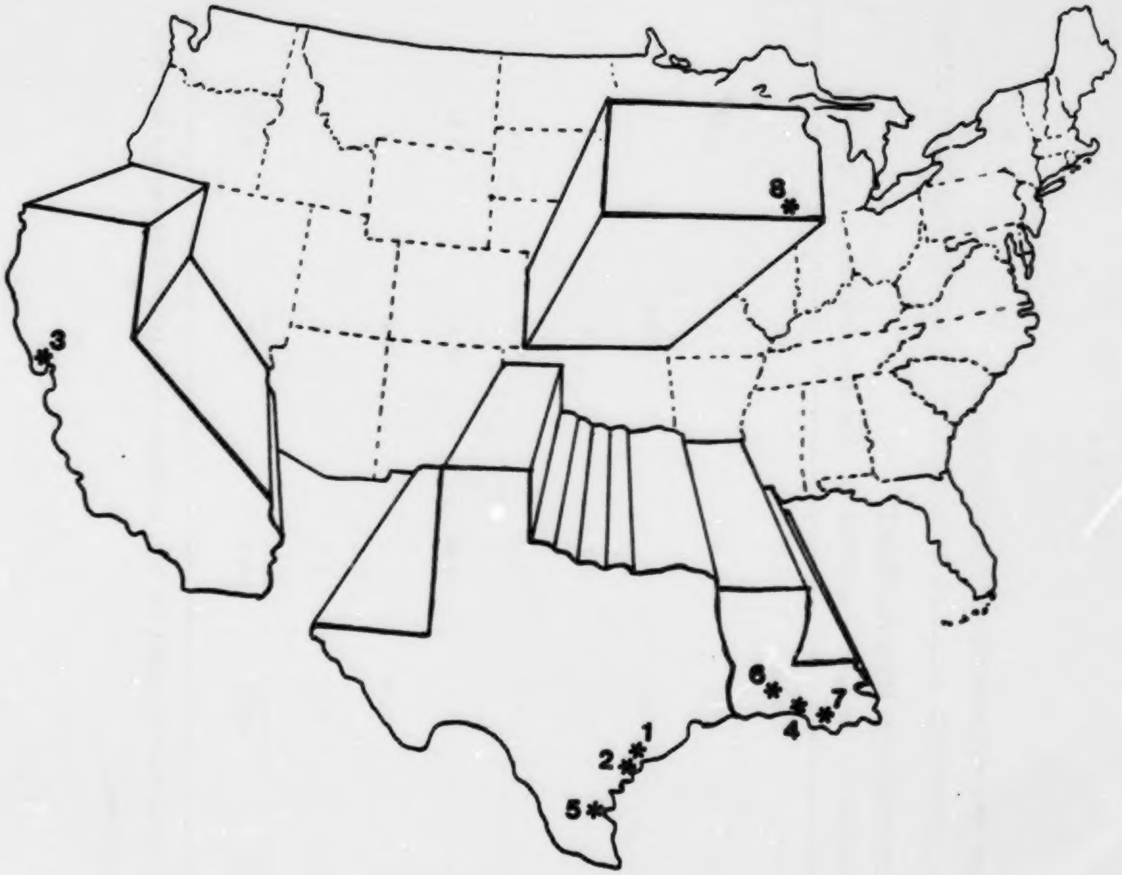
[a] Based on equipment count provided by plants and SOCMI fugitive emission factors except for Dow, Pittsburg which is based on company test data.

[b] Based on storage tank information provided by plants and AP-42 equations.



(1) Diamond Shamrock Corporation, Deer Park, Texas

(2) Dow Chemical U.S.A., Freeport, Texas

(3) Dow Chemical U.S.A., Pittsburg, California

(4) Dow Chemical U.S.A., Plaquemine, Louisiana

(5) E.I. duPont de Nemours and Company, Inc., Corpus Christi, Texas

(6) PPG Industries, Inc., Lake Charles, Louisiana

(7) Vulcan Materials Company, Geismar, Louisiana

(8) Vulcan Materials Company, Wichita, Kansas

Figure 2-1. Locations of perchloroethylene production facilities.

Although the business slowdown of the early 1980's cut overall demand for chlorinated solvents, the principle reason for PCE drop-off was the continuing trend toward lower consumption for apparel dry cleaning and other textile-related applications. This is primarily responsible for the anticipated capacity production decrease in 1985 of 18 percent. Increased recycling of the solvent in the dry cleaning and degreasing industries will also limit future growth.

2.2 PRODUCTION PROCESSES

PCE was first prepared in 1821 by Faraday from hexachloroethane.[3] Different methods of PCE preparation were developed by Regnault in 1884, Meyer in 1884, and Combes in 1887. Industrial production began in the in United States about 1925. Acetylene was the raw material in the early production processes, but its high cost has resulted in current PCE production primarily from the following three processes.

2.2.1 Chlorination of Ethylene Dichloride

Two companies produced PCE in 1983 via the chlorination of EDC. These companies are Diamond Shamrock in Deer Park, TX and Dow Chemical U.S.A. in Freeport, TX.

2.2.1.1 Process Description.[4] PCE and TCE are co-produced from the chlorination of EDC. Reaction conditions control the final production formation. Changes in the EDC/chlorine ratio determine which compound will be formed in the greatest quantity. The chlorination process occurs according to the noncatalytic reaction:

$$\underset{\text{(ethylene dichloride)}}{ClCH_2CH_2Cl + 3Cl_2} \xrightarrow{400\text{-}450°C} \underset{\text{(perchloroethylene)}}{Cl_2C = CCl_2 + 4HCl}$$

The reaction is usually carried out at about 400° to 450°C (750° to 850°F) and at a pressure slightly above one atmosphere. The process flow diagram is shown on Figure 2-2.

2.2.1.2 Current Emissions and Controls. The primary types of emissions from this process at the two production facilities are from process vents, storage, fugitives, equipment openings, and handling. The emission types and their controls are discussed below and listed in Table 2-3.

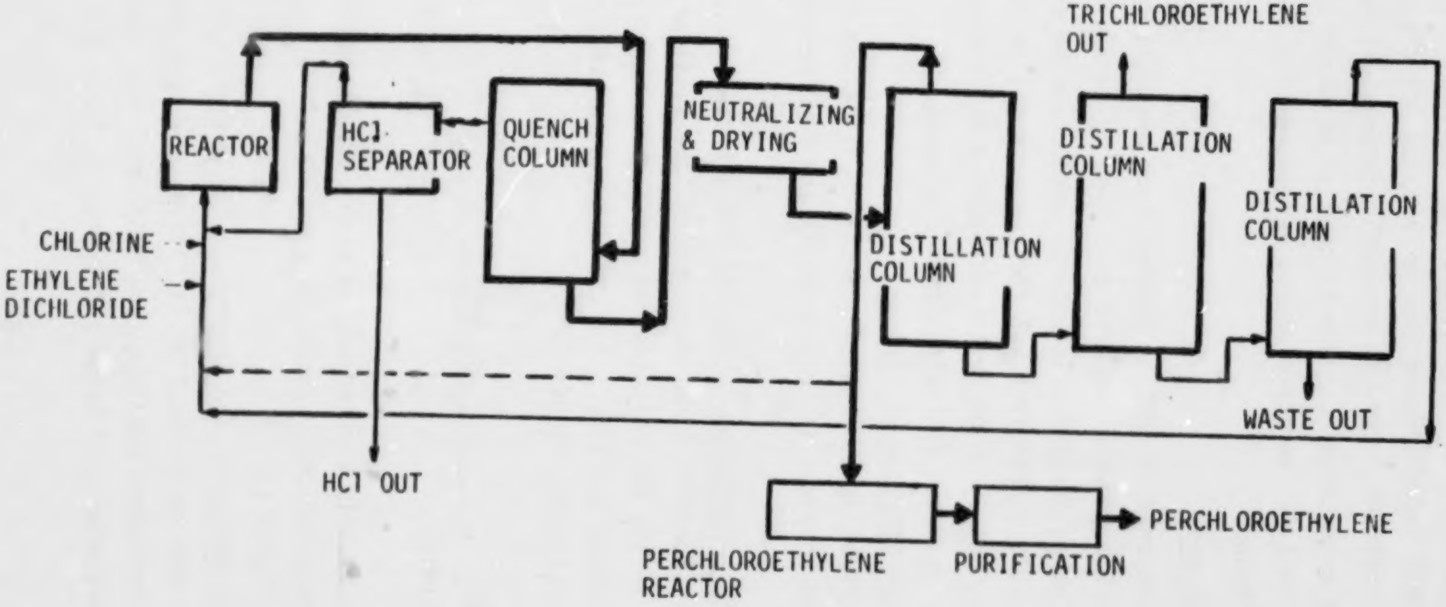

REACTOR
HCl SEPARATOR
QUENCH COLUMN
NEUTRALIZING & DRYING
DISTILLATION COLUMN
TRICHLOROETHYLENE OUT
DISTILLATION COLUMN
DISTILLATION COLUMN
CHLORINE
ETHYLENE DICHLORIDE
WASTE OUT
HCl OUT
PERCHLOROETHYLENE
PERCHLOROETHYLENE REACTOR
PURIFICATION

Figure 2-2. Process flow diagram for the production of perchloroethylene by the chlorination of ethylene dichloride.

TABLE 2-3. CURRENT CONTROLS AND ESTIMATED EMISSIONS AT FACILITIES PRODUCING PERCHLOROETHYLENE BY THE CHLORINATION OF ETHYLENE DICHLORIDE

Company/Location	Type of Emission/Source	Present Controls	Reported Control Efficiency (%)	Present PCE Emissions (Mg/yr)	Comments
Diamond Shamrock/ Deer Park, TX	Process Vents				
	• Water wash tank vent	Water blanket and vent chiller	98[a]	Minimal	
	• Crude drying column vent	Vent chiller	68.7	0.13	
	• Drying column feed tank	Water blanket	98[a]	Minimal	
	• Recycle and byproduct feed tanks vent	Brine Chiller	97	0.0003	
	• Startup vent neutralizer scrubber	Brine Chiller	N/A	0.010	Operates only during reactor startups (30 hrs/yr)
	• Flue-gas (FG) Column feed tank	None	N/A	3.800	
	• FG Column overhead decanter	Water blanket	98[a]	2.000	
	• Finished PCE surge tank	None	N/A	.0009	
	• Dry organics vent chiller	Brine chiller	95	2.420	
	• Heavy ends column vacuum pump	None	N/A	0.20	
	• Heavy ends stream stripper vent	None	N/A	Minimal	
	• 5th tray bottoms and heavy ends holding tanks	Vent chiller	98[a]	0.23	
	• Organics collection tanks and crude tanks	Vent chiller	70	0.23	
	• Continuous stripper vent	Vent chiller			Also a condenser on this vent stream
	• Organics settling tank	None	N/A	0.001	
	Storage				
	• Fixed-roof tank	None	NA	3.6	40,000 gallons
	• Fixed-roof tank	None	NA	3.6	40,000 gallons
	• Fixed-roof tank	None	NA	3.6	40,000 gallons
	• Fixed-roof tank	None	NA	3.6	40,000 gallons
	• Fixed-roof tank	None	NA	7.8	100,000 gallons
	• Fixed-roof tank	None	NA	7.8	100,000 gallons
	• Fixed-roof tank	None	NA	6.5	80,000 gallons
	• Fixed-roof tank	None	NA	12.9	160,000 gallons
	• Fixed-roof tank	None	NA	12.9	500,000 gallons
	• Fixed-roof tank	None	NA	12.9	160,000 gallons
	Fugitive	None	NA	138.4	
	Handling				
	• Tank cars	Submerged fill pipe loading	50	3.8	Emissions calculated from AP-42

TABLE 2-3 (CONCLUDED)[a]. CURRENT CONTROLS AND ESTIMATED EMISSIONS AT FACILITIES PRODUCING PERCHLOROETHYLENE BY THE CHLORINATION OF ETHYLENE DICHLORIDE

Company/Location	Type of Emission/Source	Present Controls	Reported Control Efficiency (%)	Present PCE Emissions (Mg/yr)	Comments
Diamond Shamrock/ Deer Park, TX	Secondary				
	• 5th-tray column bottoms	Commercial deep well injection	98[b]	negligible	
	• Stream stripper solids	Incinerator or commercial landfill	98[b]	negligible	
	• Filter cartridges (spent)	commercial disposal	98[b]	negligible	Packaged in closed steel drums
	• Wastewater	Biological wastewater treatment	N/A	unknown	
	• Other	N/A	N/A	N/A	Equip. maintenance, spill cleanup, general plant cleanup
Dow Chemical Freeport, TX	Process Vents				
	• PCE tank vent	None	NA	4.3	
	• Vent recovery	*	*	15.2	
	• PCE tank vent	None	NA	0.04	Total 1983 emission duration was 72 hours
	Storage				
	• *	*	*	4.8	
	• *	*	*	10.0	
	• *	*	*	4.8	
	• *	*	*	0.16	
	• *	*	*	0.17	
	• *	*	*	0.27	
	Fugitive	None	NA	80.4	
	Equipment Openings				
	• 250 openings	None	NA	0.23	
	Handling				
	• Tank cars • Tank trucks • Barges • Ships	N/A	N/A	0.07	
	Secondary				
	• Stream #72	Permitted wastewater canal	NA	0.1	

---

[a] Although the plant reported 99.99% control efficiency, only 98% is accepted when sampling data are not available.

[b] Since no PCE was released to the atmosphere from the stream, control efficiency of the treatment/disposal method was considered to be 98%.

*The company considered this to be confidential information.

N/A - Not available.

NA - Not applicable.

Diamond Shamrock Corporation - Deer Park, TX[5]

The production of PCE by EDC chlorination at this facility resulted in total emissions of PCE of 226.2 Mg in 1983. Fugitive emissions accounted for a majority of these emissions, totalling 138.4 Mg/yr. The largest sources of equipment leaks were flanges, open-ended lines, and valves. Emissions from the valves were approximately 44 Mg/yr (31 percent of total fugitive emissions). Seventeen percent of the fugitive emissions were from flanges. Open-ended lines in liquid service constituted 19 percent of these emissions. Diamond Shamrock indicated that there is currently no formal monitoring procedure for fugitive emissions. Operating personnel are instructed to report any leaking components that they observe on their normal rounds.

The TACB has recently promulgated regulations that will require a formal fugitive emissions monitoring program. The first round of monitoring must be completed by the end of 1987. The regulation will require the periodic testing of all valves in VOC service with a portable hydrocarbon meter, capping of open-ended lines and valves, monitoring of pump seals, and detailed recordkeeping of these practices.

Losses from product storage in 10 fixed-roof storage tanks were approximately 75 Mg/yr. These tanks ranged in size from 40,000 gallons to 500,000 gallons, averaging 126,000 gallons. Storage tanks in Harris County, Texas, with a capacity greater than 42,000 gallons (158,487 liters) but storing liquids with a vapor pressure less than 76 kPa (11 psia), are required to have an internal or external floating roof with primary seals and secondary seals between the tank wall and roof edge, or a vapor recovery system which returns vapor to a disposal system. For tanks greater than 42,000 gallons storing liquids with vapor pressure greater than 76 kPa (11 psia), a submerged fill pipe and vapor recovery system is required. However, Diamond Shamrock reported that there were no emission controls on these tanks.

Fourteen process vents emitted approximately 9.0 Mg of PCE emissions in 1983. The vents were located on process equipment such as columns (distillation, stripper) and various holding tanks. Condensation systems were used on a number of these vents for product recovery or emissions control. The vent with the largest quantity of emissions (3.8 Mg/yr) was on a column feed tank. There were no controls for this vent, which accounted for 42 percent of the total PCE emissions from process vents. The next two largest emissions sources were a column overhead decanter and a tank for dry organics. The column vent released 2.0 Mg of PCE. A water blanket achieved a control efficiency of 98 percent. The tank vent released 2.4 Mg/yr of PCE emissions and achieved a control efficiency of 95 percent with a vent chiller. Fifty-nine percent control efficiency was achieved for the remaining 9 percent of the process vent emissions.

Regulations for emissions from vent streams in Harris County specify that certain VOC classes, which include PCE, must be burned properly at a temperature equal to or greater than 1,300°F (704°C) in a smokeless flare or direct-flame incinerator before it is allowed to enter the atmosphere. However, the vent streams at Diamond Shamrock are exempt from this regulation. Section 115.163 specifies that vent gas streams having a combined weight of VOC's greater than 100 lbs (45.5 kg) in any consecutive 24-hour period but less than 250 lbs (113.4 kg) per hour averaged over any consecutive 24-hour period and having a true vapor pressure of less than 0.44 psia (3.0 kPa) are exempt from regulatory control. The vent with the largest quantity of PCE emissions at Diamond Shamrock releases an average of only 0.43 kg/hr (10.4 kg in any 24-hour period).

Losses due to handling were approximately 3.8 Mg/yr. All raw materials for the PCE process are received by pipeline, either into surge tanks, or directly into the reactors. The PCE product is shipped by tank cars, tank trucks, and barges. A small fraction is drummed and shipped in 55-gallon drums. To reduce emissions, all loading, except to drums, is done by the submerged fill pipe method, with an estimated control efficiency of 50 percent. This facility is exempt from the handling/loading regulations because the vapor pressure of PCE is below the cutoff limit of 1.5 psia.

Although there are four waste stream sources for secondary emissions, Diamond Shamrock reported that no PCE was emitted to the atmosphere. Two streams of column bottoms are incinerated or deep well injected. Spent filter cartridges are drummed (1 to 2 55-gallon drums/month) and sent to a commercial landfill. A wastewater stream is treated biologically in a wastewater treatment plant.

Dow Chemical U.S.A. - Freeport, TX[6]

Fugitive emissions are the largest quantity of PCE emissions generated by the chlorination of EDC at this facility. Approximately 80.4 Mg were emitted in 1983. Flanges were the source of more than 70 percent of the emissions while 25 percent were emitted from valves. Dow indicates that an automatic sampling system continuously monitors all cooling and contaminated process water leaving the unit and alarms the control room if the concentrations exceed pre-set limits. An "ultrasonic leak survey" is conducted semiannually. Six process streams are monitored internally, continuously for water contamination that would cause accelerated corrosion.

A brief discussion on the formal fugitive emissions monitoring program that will take effect in Texas in 1987 is contained in the previous discussion for Diamond Shamrock, Deer Park, TX. Currently, there are no State regulations for fugitive emissions.

Approximately 19.5 Mg of PCE were released to the atmosphere from three process vents in 1983. There are no controls on any of the vents. A vent on a PCE holding tank released 4.3 Mg/yr of PCE. A second vent on the Perchlor tank emitted only 0.037 Mg/yr of PCE. The total emission duration in 1983 was only 72 hours for this vent. The third vent emitted 15.2 Mg of PCE in 1983. All other information concerning this vent was considered confidential by Dow. Brazoria County is in a nonattainment area where regulations specify that PCE emissions from vent streams must be burned properly at a temperature equal to or greater than 1,300°F (704°C) in a smokeless flare or direct-flame incinerator. All process vents at this plant are exempt from regulation due to the vapor pressure cutoff of 0.44 psia.

PCE emissions from product storage in 1983 were 15.4 Mg. Storage and emissions control information are considered confidential by Dow. Storage control regulations in Brazoria County are identical to those in Harris County.

The PCE emissions from approximately 250 equipment openings in 1983 were 0.2 Mg. All losses were confined to evaporation from small containers used to drain residual liquid from the equipment. These containers were emptied into a liquid dumpster and sent off to be destroyed in a thermal oxidizer.

Losses from loading/handling were approximately 0.07 Mg/yr. The loading of PCE was done through the "open domes" of tank cars, tank trucks, ships, and barges. However, this facility is exempt from loading/handling regulations because liquids with vapor pressures of less than 1.5 psia are exempt from regulation in Texas.

Secondary emissions from one wastewater stream were 0.125 Mg. The stream was released into a permitted wastewater canal for disposal, but no additional description of the stream was provided by Dow.

2.2.2 Hydrocarbon Chlorinolysis

The majority of the PCE produced in 1983 was produced by the hydrocarbon chlorinolysis process. Three companies use the process at five different locations. These companies are Dow Chemical U.S.A. in Pittsburg, CA and Plaquemine, LA, Vulcan Chemicals in Wichita, KS and Geismar, LA, and E.I duPont de Nemours & Company in Corpus Christi, TX.

2.2.2.1 Process Description.[7] The process involves the gas-phase cracking of propane-propylene mixtures into C_1 and C_2 fragments along with chlorinolysis at 450°to 550°C. This yields a mixture of PCE, CCl_4, and hydrochloric acid (HCl), as shown below.

$$\underset{\text{(propane)}}{C_3H_8} + 8Cl_2 \longrightarrow \underset{\text{(perchloroethylene)}}{Cl_2C = CCl_2} + CCl_4 + 8HCl$$

$$\underset{\text{(propylene)}}{2C_3H_6} + 16Cl_2 \longrightarrow \underset{\text{(perchloroethylene)}}{Cl_2C = CCl_2} + 4CCl_4 + 12HCl$$

The process flow diagram is shown on Figure 2-3.

2.2.2.2 Current Emissions and Controls. Emission types, controls, control efficiencies, and PCE emissions for each facility producing PCE by

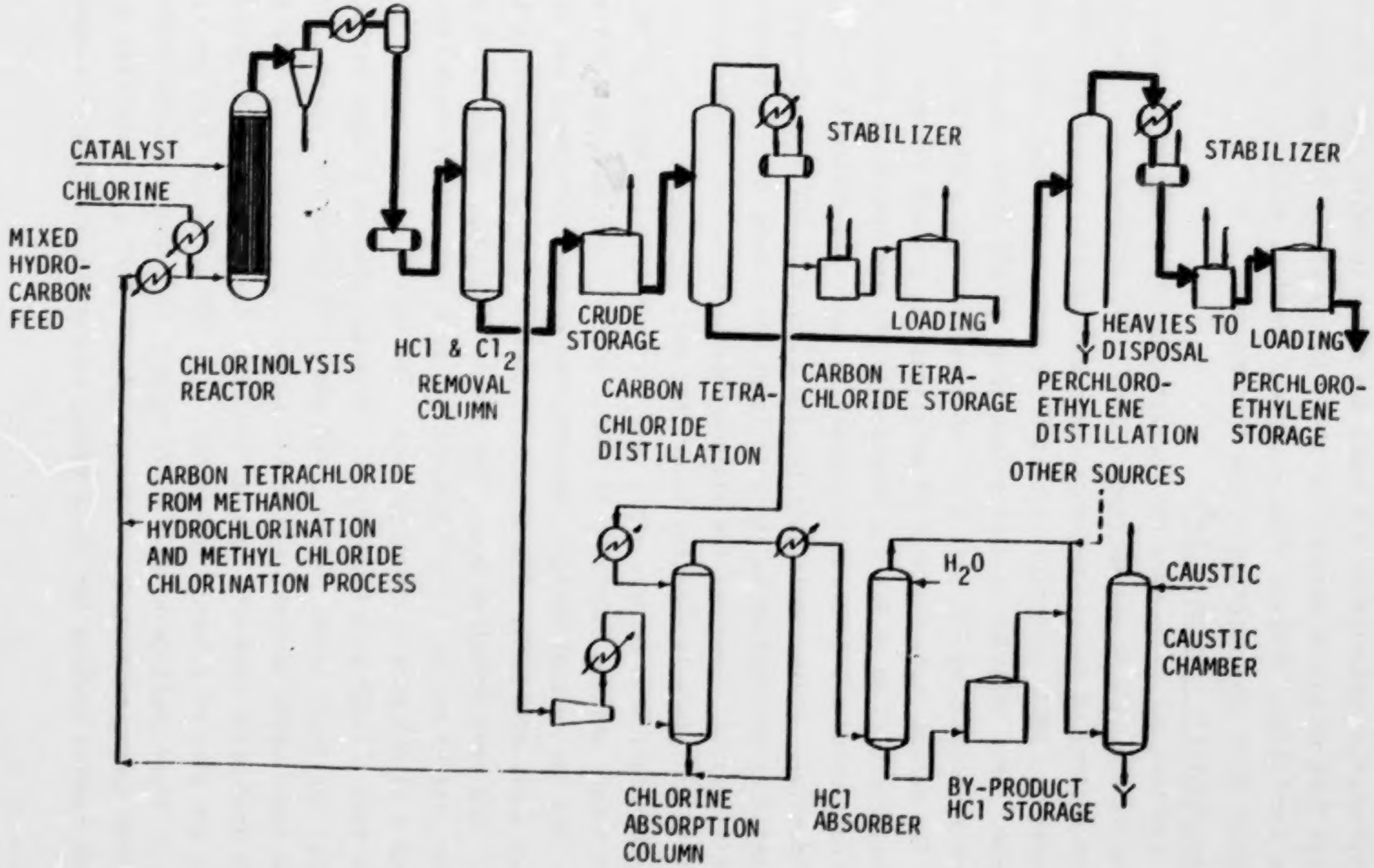

CATALYST
CHLORINE
MIXED HYDRO- CARBON FEED
CHLORINOLYSIS REACTOR
HCl & Cl_2 REMOVAL COLUMN
CRUDE STORAGE
CARBON TETRA- CHLORIDE DISTILLATION
STABILIZER
LOADING
CARBON TETRA- CHLORIDE STORAGE
PERCHLORO- ETHYLENE DISTILLATION
HEAVIES TO DISPOSAL
STABILIZER
LOADING
PERCHLORO- ETHYLENE STORAGE
CARBON TETRACHLORIDE FROM METHANOL HYDROCHLORINATION AND METHYL CHLORIDE CHLORINATION PROCESS
OTHER SOURCES
H_2O
CAUSTIC
CAUSTIC CHAMBER
CHLORINE ABSORPTION COLUMN
HCl ABSORBER
BY-PRODUCT HCl STORAGE

Figure 2-3. Process flow diagram for the production of perchloroethylene by hydrocarbon chlorinolysis.

the hydrocarbon chlorinolysis process are shown in Table 2-4. Fugitive and storage tank emissions account for the majority of the PCE emissions from these facilities. Process vent, equipment opening, handling, and secondary emissions were also reported by the five plants.

Vulcan Chemicals - Geismar, LA[8]

Fugitive emissions were the largest quantity of PCE emissions. Approximately 60.0 Mg was emitted in 1983. All information concerning fugitive emission sources was considered confidential by Vulcan. Effective December 31, 1987, Louisiana regulations require a VOC leak patrol/repair program. This includes quarterly leak check of all lines, vessels, and equipment containing PCE with a portable gas chromatograph (GC).

The second largest source of emissions was product storage. Approximately 23 Mg of PCE was released to the atmosphere in 1983. Vulcan also considered all information concerning tanks and controls to be confidential. State regulations for the storage of VOC's in storage tanks in Louisiana are similar to those in Texas which were described previously in this chapter. However, the minimum storage capacity (40,000 gallons) for tanks in Louisiana is slightly lower than that for Texas.

Emissions from process vents were approximately 2.2 Mg/yr of PCE. A "perc tower" emitted 0.0091 Mg in 1983. Vulcan reported that a pressure tower was the control device. However, the control efficiency was reported as not applicable (NA). The process is operating under pressure in the tower, and vent emissions occur from pressure buildup. There is no actual add-on control device. The PCE emissions from two solvent check tanks (ST-6A & ST-6B) were 0.127 Mg/yr each. The emissions from another solvent check tank (ST-6C) were 0.068 Mg/yr. Nitrogen padding is used for emissions control for these tanks. Tanks ST-6A and ST-6B alternate service. One of these tanks vents continuously at all times. Tank ST-6C vents only during batch production runs of a special product. The four remaining process vents are also on solvent check tanks. The PCE emissions from the vents on each of these check tanks were 0.472 Mg/yr. Each tank vents 25 percent of the time during production. Although "glycol pots" are identified by Vulcan as the control devices for these tanks, no control efficiency is reported.

TABLE 2-4. CURRENT CONTROLS AND ESTIMATED EMISSIONS AT FACILITIES PRODUCING PERCHLOROETHYLENE BY THE HYDROCARBON CHLORINOLYSIS PROCESS

Company/Location	Type of Emission	Present Controls	Reported Control Efficiency (%)	Present PCE Emissions (Mg/Yr)	Comments
Vulcan Chemicals/ Geismar, LA	Process Vents				
	• PCE tower	Pressure tower	N/A	0.009	
	• Solvent check tank	N_2 pad	N/A	0.13	
	• Solvent check tank	N_2 pad	N/A	0.13	
	• Solvent check tank	N_2 pad	N/A	0.068	
	• Solvent check tank	glycol pot	N/A	1.9	4 tanks
	Storage				
	• *	*	*	23.4	
	Fugitive	*	*	59.8	
	Equipment Openings	*	*	0.004	
	Secondary	*	*	0.17	
Vulcan Chemicals Wichita, KS	Storage				
	• *	*	*	15.8	
	Fugitive	*	*	40.8	
	Equipment Openings	*	*	0.82	
	Handling	*	*	0.70	
Dow Chemical U.S.A./ Pittsburg, CA	Process Vents				
	• Distillation column reflux drums	Back pressure regulator	*	0[a]	Vents upon startup or change in reflux temperature
	Storage				
	• Fixed-roof tank	None	NA	1.3	17,000 gallons
	• Fixed-roof tank	None	NA	1.3	17,000 gallons
	• Fixed-roof tank	Back pressure regulator	Slight[a]	7.3	300,000 gallons
	• Fixed-roof tank	Back pressure regulator	Slight[a]	3.9	310,000 gallons
	Fugitive	None	NA	0.41	
	Equipment Opening	None	NA	0.34	300 openings

TABLE 2-4 (CONCLUDED). CURRENT CONTROLS AND ESTIMATED EMISSIONS AT FACILITIES PRODUCING PERCHLOROETHYLENE BY THE HYDROCARBON CHLORINOLYSIS PROCESS

Company/Location	Type of Emission	Present Controls	Reported Control Efficiency (%)	Present PCE Emissions (Mg/Yr)	Comments
Dow Chemical U.S.A./ Pittsburg, CA	Handling				
	• Tank trucks • Rail cars • Drums • Ships	None	N/A	1.1	
Dow Chemical U.S.A./ Plaquemine, LA	Process Vents				
	• Exchanger	None	N/A	8.1	Emissions determined by direct sampling
	• Thermal oxidizer	None	98[b]	0.34	
	Storage				
	• Fixed-roof tank	Normal API pad/depad	N/A	-	45,300 gallons
	• Fixed-roof tank	Normal API pad/depad	N/A	-	45,300 gallons
	• Fixed-roof tank	Refrigeration (-5°F)	90	-	312,800 gallons
	Fugitive	None	NA	55.8	12 carbon disc relief devices
	Equipment Openings	None	NA	2.2	
	Handling	*	*	3.6	
	Secondary				
	• Containment & storm waters	Steam stripping, incineration	-	0.05	Handling losses
	• Water outfall	Direct discharge	-	0.47	
	• Filter media	Incineration	-	0.007	Handling losses
E.I. duPont de Nemours & Co/ Corpus Christi, TX	Process Vents				
	• Chlorocarbons sniff scrubber	None	NA	0.21	
	Storage				
	• Contact internal floating roof	Conservation vent	N/A	0.60	3 tanks; mechanical shoe, primary only
	• Contact internal floating roof	Conservation vent	N/A	0.37	
	• Fixed-roof	Conservation vent	N/A	0.0008	
	Fugitive	None	NA	13.6	
	Equipment Openings	None	NA	0.09	24 openings

[a] Values reported by facility.
[b] Since no PCE was released to the atmosphere from the stream, control efficiency of the treatment/disposal method was considered to be 98%.
* The company considered this to be confidential information.
N/A = Not available
NA = Not applicable

Emissions from equipment openings were approximately 0.004 Mg/yr of PCE. Information concerning the number and types of equipment controls is considered confidential by Vulcan. These emissions are well below the limits which are the same as those for process vents.

Vulcan Chemicals - Wichita, KS[9]

The largest quantity of emissions generated by the hydrocarbon chlorinolysis process at this plant was from fugitive emissions. PCE fugitive emissions in 1983 were approximately 40.1 Mg. Product storage tanks released 15.8 Mg of PCE to the atmosphere in 1983. Emissions from handling and equipment openings were 0.7 Mg/yr and 0.8 Mg/yr, respectively. All information concerning equipment and controls is considered confidential by Vulcan.

There are no regulations in Kansas for fugitive, storage, or handling and equipment openings emissions.

Dow Chemical U.S.A. - Pittsburg, CA[10]

The fugitive emissions from PCE production at this facility are based on testing performed in July 1981 by Science Applications, Inc., (SAI).[11] The data indicated an average of 0.41 Mg/yr of fugitive emissions with a 90 percent confidence interval of 0.1 to 0.72 Mg/yr. This compares with about 45 Mg/yr based on uncontrolled SOCMI fugitive emission factors applied to the equipment count at the Pittsburg plant. It should be noted that Regulation 8, Rule 22 of the Bay Area Air Quality District does not apply to this facility due to the vapor pressure cutoff of 1.5 pisa. Dow did not report a formal inspection and maintenance program, although it did indicate that its operators make an hourly inspection of the plant.

Dow reported that there were no controlled pressure relief devices in PCE service. The plant has a yearly inspection of all pressure relief devices. The relief valves are removed, tested, adjusted if necessary, and then put back in service.

Approximately 13.8 Mg/yr of PCE was emitted from product storage tanks. Two 17,000-gallon fixed-roof tanks emitted 1.3 Mg/yr each, and had no emissions controls. A 300,000-gallon and a 310,000-gallon tank are equipped with backpressure regulators for emissions control. Dow reported that these regulators provide only "slight" control efficiency. All tanks are exempted from the Bay Area storage tank regulations due to a vapor pressure cutoff of 1.5 psia.

Dow estimated that approximately 1.13 Mg/yr of PCE was emitted due to loading/handling. No control devices are used when filling tank trucks, railcars, or ships. There are no Bay Area regulations for loading/handling operations.

Losses from 300 equipment openings were estimated by Dow to be 0.34 Mg/yr. These losses are not controlled.

The production of PCE released emissions from one process vent. Dow indicated that the losses were minimal ("0 kg/yr"). The vent is on a distillation column reflux drum. Nitrogen is added to maintain a constant pressure. A back pressure regulator opens if the pressure gets too high. The control device and control efficiency was considered confidential by Dow.

Dow Chemical U.S.A. - Plaquemine, LA[12]

The production of PCE by hydrocarbon chlorinolysis emitted 91.7 Mg of PCE in 1983. The largest quantity of emissions was fugitive emissions, totalling 55.8 Mg/yr. Thirty-two percent (18.0 Mg/yr) of the fugitives were from sample connections. Thirteen percent (7.3 Mg/yr) of the fugitive emissions were from flanges, and 37 percent (20.8 Mg/yr) from valves. Dow indicated that preventive maintenance, inspection, and monitoring programs have been established in Plaquemine, but did not indicate the frequencies of these programs. Dow reported that valves and pumps are purchased primarily on their ability to not leak.

Emissions from three fixed-roof storage tanks were estimated to be 21.4 Mg in 1983. Dow reported that two 45,300-gallon tanks used normal American Petroleum Institute (API) padding and depadding systems for emissions control. A control efficiency was not reported. These two tanks emitted 38 percent (8.0 Mg/yr) of the storage emissions. Sixty-two percent (13.3 Mg/yr) was released from a 312,800-gallon tank. Emission control was by refrigeration (-5°F). The emission control efficiency was 90 percent. Storage tanks in Louisiana with capacities greater than 40,000 gallons and containing organic compounds with vapor pressures less than 11 psia are required to have a floating roof with seals between the tank wall and roof edge, or a vapor recovery system which returns vapor to a disposal system. However, Dow did not report these controls for these three tanks.

PCE emissions from process vents were 8.2 Mg in 1983. Ninety-eight percent (8.0 Mg/yr) of these emissions were from an exchanger. There was no control device for this vent. The vent on the thermal oxidizer emitted 0.3 Mg/yr of PCE. The oxidizer is a control device used for the thermal destruction of process wastes.

Total emissions from loading/handling were 3.6 Mg/yr. Information concerning equipment and controls are considered confidential by Dow.

Equipment opening emissions totalled 2.2 Mg in 1983. There were 255 openings in equipment for gas and liquid service. These emissions are regulated under Louisiana's general VOC regulations for production processes. The hourly and daily emission limits are 1.3 kg/hr and 6.8 kg/day. However, Dow did not report if those emissions were controlled.

Secondary emissions of PCE from four waste streams totalled 0.52 Mg/yr. Organics from the containment water and storm water waste stream are stripped and incinerated in the thermal oxidizer. PCE losses due to "handling" accounted for 9 percent (0.05 Mg/yr) of the secondary emissions. One percent (0.007 Mg/yr) of the secondary emissions was from handling of the spent filter media. Ninety percent (0.47 Mg/yr) of the secondary emissions were from two water outfall streams. These are discharged to the nearest POTWs.

E.I. duPont de Nemours - Corpus Christi, TX[13]

Dupont produces PCE by hydrocarbon chlorinolysis and uses some of this product as an intermediate in the production of CFC's. The CFC's are also produced at their facility in Montague, MI.

The largest quantity of emissions is fugitive, totalling approximately 13.6 Mg/yr. The largest sources of fugitive emissions are valves, which released 32 percent (4.4 Mg/yr) of the total. Twenty-nine percent (4.0 Mg/yr) of the emissions are from pressure relief devices. Seventeen percent (2.3 Mg/yr) of the PCE fugitives were from flanges. The remaining

32 percent of the fugitive emissions were from the pump seals (1.7 Mg/yr), sample connections (0.5 Mg/yr), and open-ended lines (0.5 Mg/yr). Dupont did not indicate if any controls were being used for fugitive emissions. The formal fugitive emissions monitoring program that will take effect in 1987 in Texas has been discussed previously for other plants in Texas.

Storage emissions were approximately 0.97 Mg/yr. The emissions were from three 16,000-gallon contact internal floating-roof tanks, one 400,000-gallon contact internal floating roof tank, and one 122,000-gallon fixed-roof tank. DuPont reported that the emission controls for each tank were conservation vents. Control efficiencies were not reported. The use of internal floating roofs for storage tanks is required by State regulations in Texas.

An air exhaust system is used to collect emissions from leaks and discharges from six continuous vents, only one of which introduces PCE into the system. A chlorocarbon sniff scrubber is used to treat these emissions. Approximately 0.21 Mg/yr was released. The hourly and daily emission limits from process vents in Texas are 1.4 kg/hr and 6.8 kg/day. This scrubber vent stream is under this limit with PCE emissions of 0.024 kg/hr and 0.57 kg/day.

Losses from 24 equipment openings in PCE service were estimated to be 0.09 Mg/yr. There are no regulations in Texas for controlling these emissions.

Dupont indicated that negligible amounts of PCE were released to the atmosphere as secondary emissions from waste streams from sumps, tank sludge, and filter cartridges.

2.2.3 Oxychlorination of Ethylene Dichloride

PPG Industries developed this process and is currently the only company that uses the process to produce PCE.[14]

2.2.3.1 Process Description.[15] This process, like the chlorination process, produces both PCE and TCE. The product mix can be varied by adjusting the EDC to chlorine ratio. The reaction for PCE is shown below:

$$\mathrm{CHCl = CHCl + Cl_2/or\ HCl + O_2} \xrightarrow[\text{catalyst}]{430^\circ\mathrm{C}} \mathrm{CCl_2 = CCl_2 + 2H_2O}$$

The build-up of a great amount of hydrogen chloride is avoided by concomitantly-operating HCl oxidation. The reaction involves simultaneous oxychlorination/dehydrochlorination with chlorine or anhydrous hydrogen chloride as the chlorine source. The process flow diagram is shown on Figure 2-4.

2.2.3.2 Current Emissions and Controls. Emission types, controls, control efficiencies, and PCE emissions from the production of PCE by the oxychlorination of EDC at PPG Industries are shown in Table 2-5. The major sources of emissions were fugitive emissions and storage tanks. PCE emissions from process vents, loading/handling, and equipment openings were also reported.

Fugitive emissions from equipment in PCE service totalled approximately 23.5 Mg in 1983. Valves were the largest source of emissions, releasing 42 percent (10.0 Mg/yr) of the total fugitive emissions. Twenty-seven percent (7.4 Mg/yr) of the total fugitive emissions were released from pump seals. Flanges were the sources of 25 percent (5.9 Mg/yr) of the fugitive emissions. Sample connections were the sources of 4.3 percent (1.0 Mg/yr) of the PCE emissions. Twenty-one pressure relief devices released 0.7 percent (0.2 Mg/yr) of the fugitive emissions. Thirteen of the pressure relief valves were in liquid service and were equipped with rupture discs. The relief valve discharges reported by PPG occurred from July 2, 1984 to December 28, 1984, and accounted for 0.2 Mg of PCE emissions. Discharges were due to pressure build-up, overfilled tanks, and premature failure of the device. PPG reported that there were no formal inspection programs used in 1983. Leaks were located by visual observations and repaired "promptly" for economic reasons (loss of product, corrosion of equipment). Effective December 31, 1987, Louisiana regulations will require a VOC leak patrol/repair program. This includes quarterly leak checks of all lines, vessels, and equipment containing PCE with a portable GC.

PCE emissions from storage tanks in 1983 were 18.5 Mg. Eighty-nine percent (16.6 Mg/yr) of the emissions were from three fixed-roof tanks. These are dock tanks with capacities of 430,000 gallons each. There is one vent stack for these three tanks. No emission controls were reported.

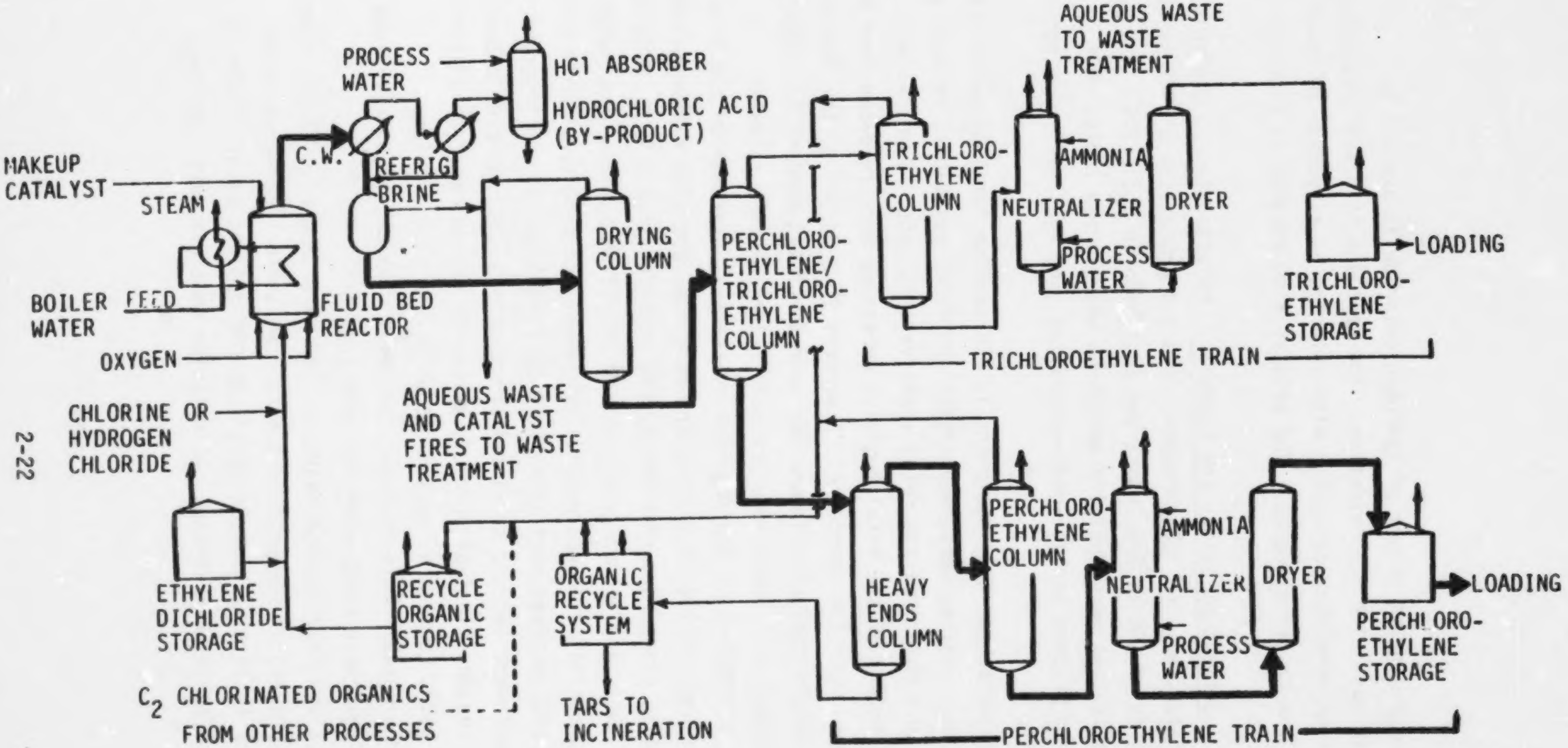

MAKEUP CATALYST
STEAM
BOILER FEED WATER
OXYGEN
CHLORINE OR HYDROGEN CHLORIDE
ETHYLENE DICHLORIDE STORAGE
C₂ CHLORINATED ORGANICS FROM OTHER PROCESSES
FLUID BED REACTOR
C.W.
REFRIG
BRINE
PROCESS WATER
HCl ABSORBER
HYDROCHLORIC ACID (BY-PRODUCT)
DRYING COLUMN
AQUEOUS WASTE AND CATALYST FIRES TO WASTE TREATMENT
RECYCLE ORGANIC STORAGE
ORGANIC RECYCLE SYSTEM
TARS TO INCINERATION
PERCHLORO-ETHYLENE/TRICHLORO-ETHYLENE COLUMN
TRICHLORO-ETHYLENE COLUMN
AQUEOUS WASTE TO WASTE TREATMENT
NEUTRALIZER
AMMONIA
PROCESS WATER
DRYER
TRICHLORO-ETHYLENE STORAGE
LOADING
TRICHLOROETHYLENE TRAIN
HEAVY ENDS COLUMN
PERCHLORO-ETHYLENE COLUMN
NEUTRALIZER
AMMONIA
PROCESS WATER
DRYER
PERCHLORO-ETHYLENE STORAGE
LOADING
PERCHLOROETHYLENE TRAIN

Figure 2-4. Process flow diagram for the production of perchloroethylene by oxychlorination.

TABLE 2-5. CURRENT CONTROLS AND ESTIMATED EMISSIONS AT FACILITY PRODUCING PERCHLOROETHYLENE BY THE OXYCHLORINATION OF ETHYLENE DICHLORIDE

Company/Location	Type of Emission/Source	Present Controls	Reported Control Efficiency (%)	Present PCE Emissions (Mg/yr)	Comments
PPG Industries/ Lake Charles, LA	Process Vent				
	• Still line vent scrubber	Water scrubber	NA	0.12	Emissions given only for after control device
	• Acid sump scrubber	Water scrubber	NA	0.063	
	• Emergency/startup scrubber	Water scrubber	NA	0.041	Scrubber used only 44 hours in 1983
	• DH system vent scrubber	Water scrubber	NA	Minimal	
	• #1 and #2 incinerators	Incineration	98[a]	Minimal	
	• #3 incinerator	Incineration	98[a]	Minimal	
	Storage				
	• Fixed-roof tank	Refrigeration, vapor recovery	80	1.2	2 tanks; 65,000 gals/tank
	• Fixed-roof tank	Refrigeration, vapor recovery	80	0.49	2 tanks, 13,500 gals/tank
	• Fixed-roof tank	Refrigeration, recovery	80	0.13	1 tank; 24,500 gals
	• Fixed-roof tank	Refrigeration, recovery	80	0.087	2 tanks; 13,500 gals/tank
	• Fixed-roof tank		NA	16.6	3 tanks; 430,000 gals/tank
	Fugitive	None	N/A	23.5	
	Equipment Openings	Purged (N_2), washed (H_2O), or cleared at hi-temp prior to opening	NA	0.4	37 openings
	Handling	Submerged fill pipe	NA	1.3	

[a] Although the plant reported 99.99% control efficiency, only 98% is accepted when sampling data is not available. However, reported efficiencies were used to estimate emissions.

NA - Not available.

N/A = Not applicable

Storage tanks in Louisiana are exempt if they store organic chemicals with vapor pressures less than 1.5 psia (PCE vapor pressure is about 0.3 psia). Two fixed-roof stabilization tanks were the sources of 6.5 percent (1.2 Mg/yr) of the storage tank emissions. The tank capacities are 65,000 gallons each. Refrigeration and vapor recovery is the method of emissions control, achieving a control efficiency of 80 percent. Vapor loss control devices other than internal and external floating roofs can be approved by the Technical Secretary of Louisiana if the devices control organic emissions as effectively as floating roofs. Four fixed-roof degreasing stabilization tanks were the sources of 3.1 percent (0.6 Mg/yr) of the storage emissions. The capacities of these tanks are 13,500 gallons each. There are two vent stacks for these four tanks. Emissions control is by refrigeration and vapor recovery with a control efficiency of 80 percent. One fixed-roof shipping tank was the source of 0.7 percent (0.1 Mg/yr) of the storage emissions. Emissions control on this tank is by refrigeration and vapor recovery with a control efficiency of 80 percent.

Emissions from process vents are controlled by scrubbers and totalled 0.2 Mg/yr. Fifty-three percent (0.12 Mg/yr) of these emissions were vented from a scrubber for a distillation column. No control efficiency was reported. The vent on an acid sump scrubber was the source of 29 percent (0.063 Mg/yr) of the total process vent emissions. The vent on an emergency/startup scrubber was the source of 18 percent (0.04 Mg/yr) of the process vent emissions. These were not continuous emissions because the scrubber is used only during startup, shutdowns, and brief emergencies. This scrubber was used only 44 hours in 1983. A "DH System" scrubber, which is used only in emergency situations, was not used in 1983.

Approximately 1.3 Mg of PCE was emitted from loading/handling operations in 1983. Louisiana regulations stipulate that loading facilities for VOC's with throughputs of at least 20,000 gallons/day (40,000 gallons or more for existing facilities) must be equipped with vapor collection and disposal systems. PPG used submerged fill pipes for loading/handling rail cars and tank trucks. Railcars were the sources of 34 percent (0.44 Mg/yr) of the handling emissions. Tank trucks were the sources of 17.5 percent

(0.22 Mg/yr) of the handling emissions. Submerged fill pipes were also the control measures used for loading barges and ships. Thirty-two percent (0.40 Mg/yr) of the handling/loading emissions occurred at barges; 16 percent (0.20 Mg/yr) occurred at ships. However, barges and ships are exempt from these loading/handling regulations.

PCE emissions from equipment openings were 0.4 Mg in 1984. The losses were from: 12 openings on 5 reactors, 20 openings on 9 distillation columns, and 5 openings on 5 tanks. PPG did not report equipment opening emissions for 1983.

2.3 REFERENCES

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8. Letter and attachments from Berg, R. E., Vulcan Chemicals, to Farmer, J. R., EPA:ESED. January 31, 1985. Response to PCE 114 letter.

9. Letter and attachments from Boyd, J. W., Vulcan Chemicals, to Farmer, J. R., EPA:ESED. February 1, 1985. Response to PCE 114 letter.

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3.0 CHLOROFLUOROCARBON PRODUCTION, BY-PRODUCT FORMATION, AND MISCELLANEOUS PRODUCTION USES

This chapter presents the emissions and controls associated with the use of PCE as an intermediate in CFC production, as a by-product formed in the production of other chlorinated hydrocarbons, and as a raw material used in the synthesis of other chemical products. Three plants use PCE as a raw material in the production of CFC's. One of these facilities is also a producer of PCE. Five plants form PCE as a by-product in the manufacture of other chlorinated hydrocarbons or use it as raw material for other processes. PCE emissions from CFC production come from equipment leaks, raw material storage, and loading and handling. Emissions sources in by-product formation includes process vents, equipment openings, secondary sources, and truck, railcar, or barge loading.

3.1 QUANTITIES CONSUMED/PRODUCED AND MANUFACTURERS

PCE is currently used as an intermediate for CFC production by two companies at three locations. The estimated total CFC production capacity for two of these plants is about 136,000 Mg/yr.[1] The estimated capacity of the third plant was not available in published literature. The producers, their locations, and capacities are listed in Table 3-1. The types and amounts of emissions from these facilities are shown in Table 3-2. The plant locations are shown in Figure 3-1.

Fluorocarbons are produced in the United States by duPont, Allied, Kaiser, Pennwalt, and Racon. Only duPont and Allied manufacture CFC's-113, (trichlorotrifluoroethane), -114 (dichlorotetrafluoroethane), -115 (chloropentafluoroethane), and -116 (hexafluoroethane), which use PCE as an intermediate. It is estimated that duPont supplies about 70 percent of this market with Allied selling the remainder.[1] Although a large amount of the CFC's are sold directly by the producers, most is reportedly sold through distributors.

TABLE 3-1. CHLOROFLUOROCARBON PRODUCTION FACILITIES USING PCE AS AN INTERMEDIATE

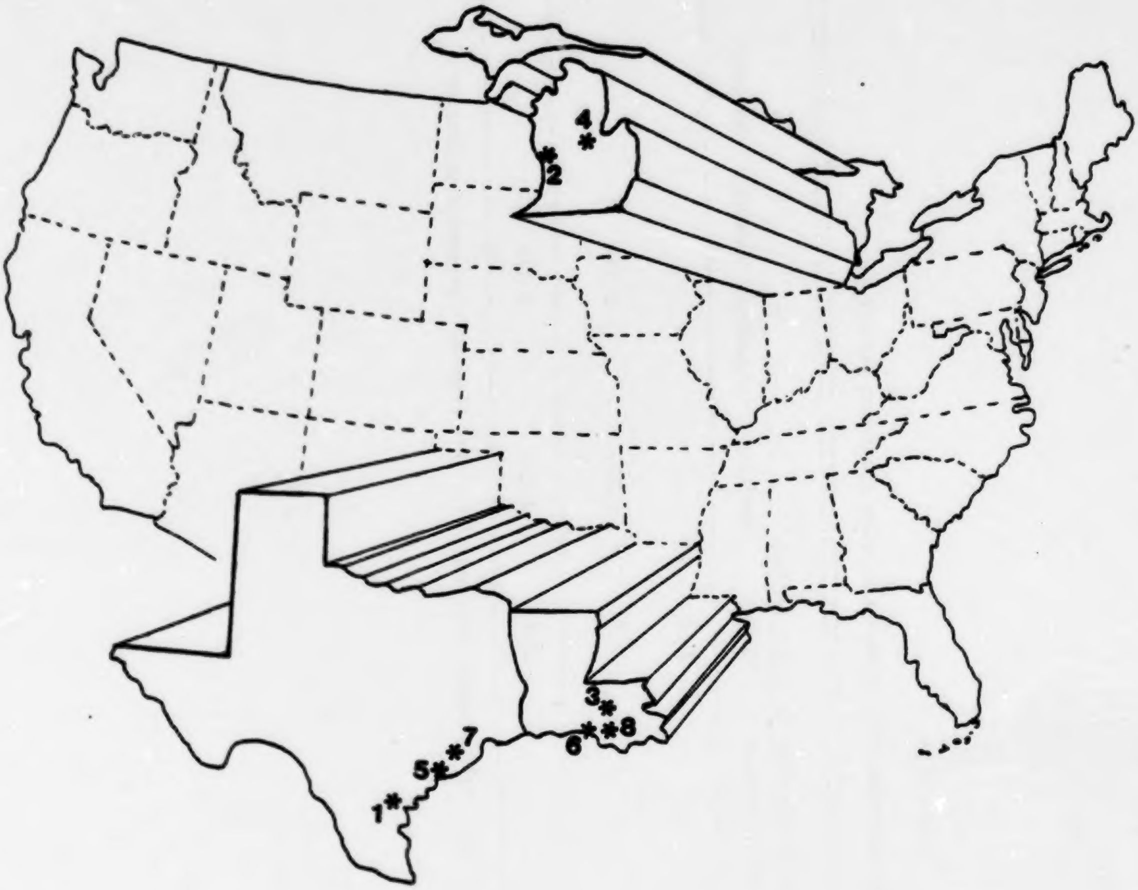
Company	Location	Capacity (Mg/yr) (1984)
Allied Corporation	Baton Rouge, LA	45,300
E.I. duPont de Nemours	Montague, MI	a
E.I. duPont de Nemours	Corpus Christi, TX	90,600

[a] The capacity for this facility could not be found in available literature.

TABLE 3-2. TOTAL PCE EMISSIONS FROM CHLOROFLUOROCARBON PRODUCTION FACILITIES

Plant/Location	1983 Perchloroethylene Emissions (Mg/yr)							
	Process	Fugitive	Relief Devices	Storage	Handling	Equipment Openings	Secondary	Total (Mg/yr)
Allied Corporation Baton Rouge, LA	-	8.2	-	11.5	-	-	-	19.7
E.I. duPont de Nemours Montague, MI	-	8.7	-	6.0	0.016	0.033	-	14.7
TOTAL	-	16.9	-	17.5	0.016	0.033	-	34.4

[a] The duPont plant at Corpus Christi, TX is also a producer of PCE. All emissions information for this plant were presented in Chapter 2



(1) E.I. duPont de Nemours and Company, Inc., Corpus Christi, Texas
(2) E.I. duPont de Nemours and Company, Inc., Montague, Michigan
(3) Allied Corporation, Baton Rouge, Louisiana
(4) Dow Chemical U.S.A., Midland, Michigan
(5) Dow Chemical U.S.A., Freeport, Texas
(6) Georgia Gulf, Plaquemine, Louisiana
(7) Shell Oil Company, Deer Park, Texas
(8) Borden Chemicals, Geismar, Louisiana

Figure 3-1. Locations of CFC producers using PCE and miscellaneous production facilities.

3.2 CHLOROFLUOROCARBON PRODUCTION PROCESS

The major consumptive use of PCE is in the manufacture of CFC's. PCE is a chemical intermediate in the synthesis of CFC-113, CFC-114, CFC-115, and CFC-116. These CFC's are used chiefly as refrigerants. Their use for aerosol sprays was prohibited as of 1979 because of their potential to contribute to stratospheric ozone depletion.[1]

3.2.1 Chlorofluorocarbon Production

Two companies at three facilities used PCE as an intermediate in the production of CFC's in 1983. These companies are E.I. duPont de Nemours in Corpus Christi, TX and Montague, MI, and Allied Corporation in Baton Rouge, LA. Dupont also produces PCE at the Corpus Christi facility.

3.2.1.1 Process Description.[2] CFC-113 and CFC-114 are co-produced as part of an integrated process within the same facility. The only commercially important domestic process used to produce these two compounds involves the liquid-phase catalytic reaction of anhydrous hydrogen fluoride with chlorinated hydrocarbons (PCE and/or CCl_4) and chlorine. For PCE feedstock, the net reaction can be represented as follows:

$$\underset{(PCE)}{2Cl_2C = CCl_2} + 7HF + 2Cl_2 \xrightarrow[\text{catalyst}]{SbCl_5} \underset{(CFC\text{-}113)}{C_2Cl_3F_3} + \underset{(CFC\text{-}114)}{C_2Cl_2F_4} + 7HCl$$

A portion of CFC-114 produced by this method can be isolated for consumption in a separate reaction with anhydrous hydrogen fluoride to yield CFC-115 and CFC-116.

3.2.1.2 Current Emissions and Controls. The major type of PCE emissions from CFC production is from raw material storage. Fugitive emissions and loading/handling emissions were also reported. The emission types and their controls are discussed below and are summarized in Table 3-3. Since all PCE produced at the duPont facility in Corpus Christi, TX is used to manufacture CFC at the same facility and all emissions data for the plant have been discussed in Chapter 2, this facility will not be discussed in this chapter.

TABLE 3-3. CURRENT CONTROLS AND ESTIMATED EMISSIONS AT CHLOROFLUOROCARBON FACILITIES USING PCE AS AN INTERMEDIATE[a]

Company/Location	Type of Emission/ Source	Present Controls	Reported Control Efficiency (%)	Present PCE Emissions (Mg/yr)	Comments
Allied Corporation/ Baton Rouge, LA	Fugitive	None	0	8.2	
	Storage				
	● Fixed-roof tank	Submerged fill pipe	N/A	11.5	172,000 gallons
E.I. duPont de Nemours Montague, MI	Fugitive	None	0	8.7	
	Storage				
	● Fixed-roof tank	Conservation vent	0	5.3	70,000 gallons
	● Fixed-roof tank	Conservation vent	0	0.7	50,000 gallons
	Handling	None	0	0.016	
	Equip. Openings	None	0	0.033	23 openings

[a] The duPont plant at Corpus Christi, TX is also a producer of PCE. All emissions information for this plant were presented in Chapter 2.

N/A = Not available

E.I. duPont de Nemours - Montague, MI[3]

The use of PCE as an intermediate in the production of CFC's at this facility in 1983 resulted in total PCE emissions of 14.7 Mg. The majority of these emissions were fugitive emissions, which accounted for 60 percent (8.7 Mg) of PCE released to the atmosphere. The largest sources of equipment leaks were valves, open ended lines, and mechanical pump seals. Emissions from valves were approximately 4.4 Mg/yr (49 percent of total fugitive emissions). Twenty-five percent of the fugitive emissions were from open ended lines (2.2 Mg/yr) and 19 percent (1.7 Mg/yr) from mechanical pump seals. Although operators at the facilities are trained to look for and repair leaks, duPont did not indicate that there was a formal monitoring/maintenance program in place for equipment leaks. There are no regulations in Michigan requiring control of these emissions.

PCE emissions from equipment openings totalled 0.033 Mg in 1983. There were 23 openings on a variety of tanks, reactors, filters, pumps, and pipe flanges. There are no regulations in Michigan requiring control of these emissions.

PCE emissions from two fixed-roof storage tanks were 6.0 Mg in 1983. One 70,000-gallon tank released 89 percent (5.3 Mg/yr) of the total storage emissions, and a 50,000-gallon tank was the source of the remaining storage emissions (0.7 Mg/yr). There are no control devices for these tanks and none are required by State regulations since storage tanks containing VOC with vapor pressure less than 1.5 psia are exempt from control in Michigan. Dupont reported that conservation vents (venting at 0.4 psia) are the "control devices." No control efficiency was reported for these vents. Dupont indicated that no working losses (due to tank filling and emptying) occur because the tanks are vented to the railcar during PCE transfer. They also report that no breathing losses occur during plant operation because PCE is continuously fed to the process at volumes greater than the vapor expansion from ambient temperature changes. If there are no breathing or working losses, then there are no losses of PCE from storage tanks. However, these operational procedures were not considered when calculating PCE emissions from these storage tanks by using the AP-42 equations.

PCE emissions from loading/handling procedures were 0.016 Mg in 1983. The raw material (PCE) is received by railcar. The top of the car is opened for sampling and connecting the liquid and vent lines. During unloading, the storage tank is vented to the rail car. The sampling and hookup procedure is the source of emissions. The handling of PCE is not regulated by Michigan due to a vapor pressure cutoff of 1.5 psia.

Two sources of secondary emissions were reported by Dupont to release "insignificant" amounts of PCE to the atmosphere. About five drums of one unidentified waste were disposed of by incineration in 1983. Water seals were used in the drums to help prevent PCE vapors from being emitted. The emissions from the National Pollutant Discharge Elimination System (NPDES) wastes were insignificant because of the small amount of PCE in the waste water.

Allied Corporation - Baton Rouge, LA[4]

The only PCE emissions from CFC production at this facility were fugitive emissions and raw material storage emissions, which totalled 19.7 Mg/yr. Fugitive emissions accounted for 8.2 Mg of the total PCE emissions. The largest sources of PCE fugitive emissions were valves, which emitted 69 percent (5.5 Mg/yr) of the fugitive emissions. Two pressure relief devices in gas service were equipped with rupture discs and, therefore, were estimated to have no emissions. Flanges were the source of 15 percent (1.2 Mg/yr) of the fugitive emissions, and mechanical pump seals were the source of the remaining 16 percent (1.3 Mg/yr) of the fugitive emissions. Effective December 31, 1987, Louisiana regulations will require VOC leak patrol/ repair programs. This includes quarterly leak checks of all lines, vessels, and equipment containing PCE with a portable GC.

Allied did not record the number of actual equipment openings in 1983. They estimate that there would normally be less than five openings/year and that the associated quantity of emissions would be negligible.

Raw material storage was the largest source of emissions. The facility had one 172,000-gallon fixed-roof tank for PCE storage, from which about 11.5 Mg of PCE were emitted in 1983. Allied reported that the total filling and breathing losses, using AP-42 equations, was 3.1 Mg/year in 1983. This tank is exempt from control in Louisiana because of the vapor pressure cutoff of 1.5 psia. A submerged fill pipe was used for emissions control. The control efficiency was not reported.

Allied's estimates for loading/handling emissions were included within the emission losses reported for storage tanks. PCE is delivered to the facility by railcar. After the dome has been opened for lab analysis and approval, PCE is pumped into the storage tank through a hose. Air would be drawn into the tank car during pumping, and loading area emissions were, therefore, considered to be minimal. Allied included these minimal losses with their storage tank emissions estimates. The loading of CFC into tank trucks and railcars is done in a closed system where vapors within the tank trucks or cars can return to the storage tank. There is no detectable level of PCE in the product.

The only source of secondary emissions was an outfall stream consisting of treated process and utility wastewater and runoff from process areas. Allied responded that the secondary emissions were "minimal." The 0.005 mg/l concentration of PCE is well below the solubility of PCE in water of about 13 mg/l. Treatment of the stream was by equalization in ponds, monitoring, and discharge accordance with the NPDES permit.

3.3 BY-PRODUCT FORMATION AND MISCELLANEOUS USES

PCE was produced as a by-product at four facilities in the United States in 1983. It is produced as a by-product in the synthesis of other chlorinated hydrocarbons such as VC, EDC, TCE, and CCl_4. It was also used as a raw material in the production of other commercially-available products at two plants, for which all information is considered confidential by the producer. The production facilities, their locations, processes, and total PCE emissions are shown in Table 3-4.

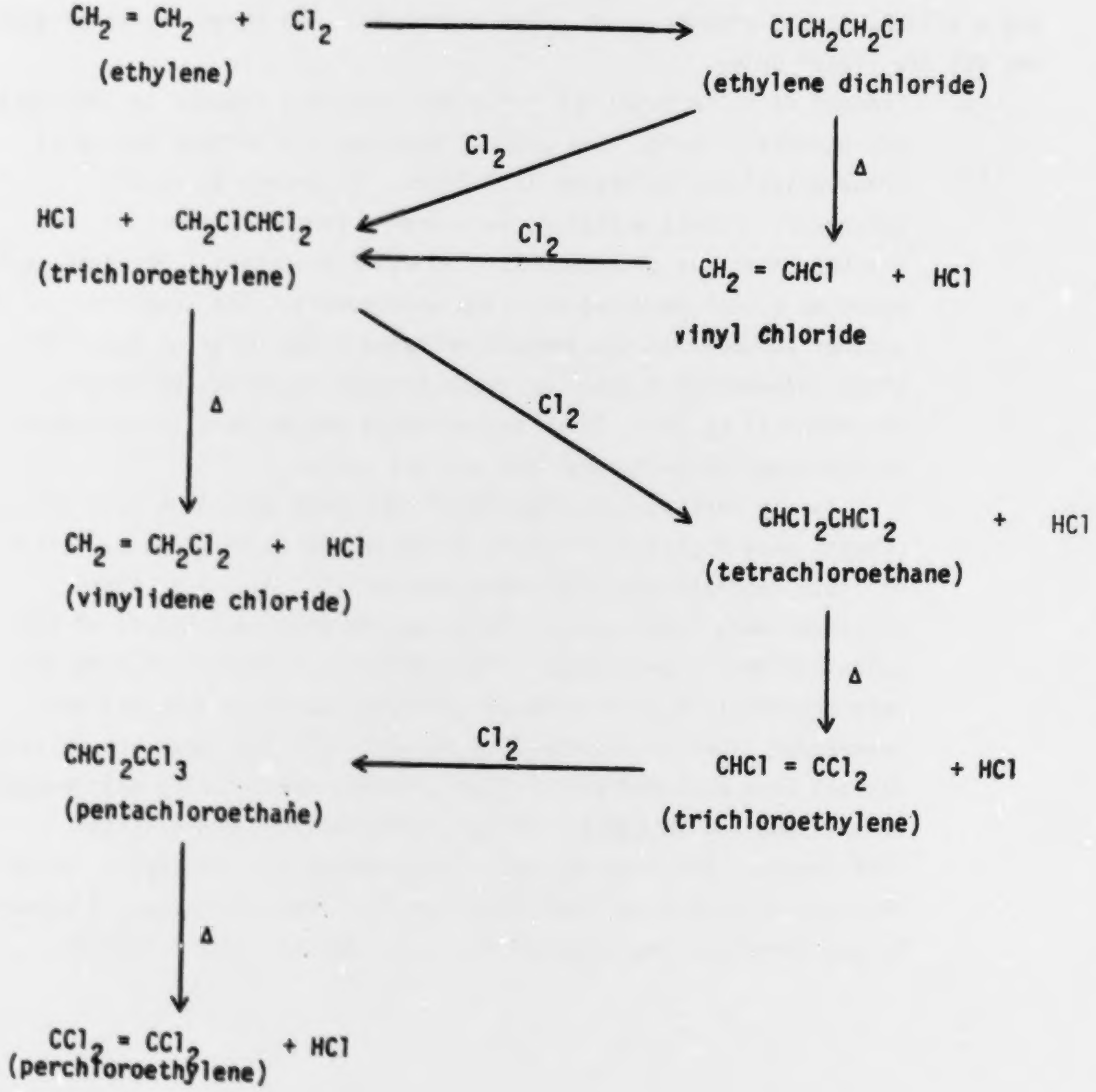
3.3.1 By-products from Chlorinated Hydrocarbon Production

Four companies at five locations produced PCE as a by-product of other chlorinated hydrocarbons in 1983. These companies were Dow Chemical U.S.A. in Freeport, TX and Midland, MI; Borden Chemical in Geismar, LA; Shell Oil Company in Deer Park, TX; and Georgia Gulf in Plaquemine, LA.

TABLE 3-4. PRODUCTION FACILITIES PRODUCING PCE AS A BY-PRODUCT OR USING PCE FOR MISCELLANEOUS PRODUCTION

Company	Location	Process	Total PCE Emissions (Mg/yr)
Dow Chemical U.S.A.	Midland, MI	Confidential production processes; PCE is raw material and solvent	172.8
Dow Chemical U.S.A.	Freeport, TX	Trichloroethylene (TCE) production; PCE is by-product Feedstock to another process	48.6
Borden Chemical	Geismar, LA	Ethylene dichloride (EDC) production; PCE is by-product	0.0004
Shell Oil Company	Deer Park, TX	Vinyl chloride monomer (VCM) production; PCE is by-product	0.30
Georgia Gulf	Plaquemine, LA	Vinyl chloride monomer (VCM) production; PCE is by-product	25.2

3.3.1.1 Process Description.[5] Using ethylene as a feedstock, changes in the subsequent chlorination (oxychlorination and dehydrochlorination) and pyrolysis stages will result in the formation of various chlorinated hydrocarbons. The relationship between these compounds can be expressed by the following sequences:


$CH_2 = CH_2 + Cl_2$
(ethylene)
$ClCH_2CH_2Cl$
(ethylene dichloride)
Cl_2
Δ
$HCl + CH_2ClCHCl_2$
(trichloroethylene)
Cl_2
$CH_2 = CHCl + HCl$
vinyl Chloride
Δ
Cl_2
$CH_2 = CH_2Cl_2 + HCl$
(vinylidene chloride)
$CHCl_2CHCl_2 + HCl$
(tetrachloroethane)
Δ
Cl_2
$CHCl_2CCl_3$
(pentachloroethane)
$CHCl = CCl_2 + HCl$
(trichloroethylene)
Δ
$CCl_2 = CCl_2 + HCl$
(perchloroethylene)

3.3.1.2 Current Emissions and Controls. The major type of PCE emissions from by-product formation and miscellaneous applications are fugitive emissions and process vent emissions. The types and amounts of emissions from these facilities are shown in Table 3-5. The emission types and their controls are discussed below and are summarized in Table 3-6.

Dow Chemical U. S. A. - Midland, MI[6]

PCE is used at the Michigan Division of Dow Chemical as a raw material and a solvent in the production of other chemicals. The three processes that use PCE are listed below.

- Process #1 - The total PCE emissions from this process in 1983 were approximately 49 Mg. One process vent was the largest source of these emissions, releasing 38.9 Mg/yr (79 percent of total emissions). These emissions were from a common vent header on a scrubber that was also used for two other processes. The data were based on actual sampling and flow measurement. The vent from another scrubber in the process released 0.004 Mg/yr of PCE. All other information concerning these process vents was considered confidential by Dow. There are no State regulations in Michigan controlling VOC emissions from process vents.

  Twenty percent (10.2 Mg/yr) of the total emissions from this process were fugitive emissions which are not controlled by Federal or State regulations. Fifty-one percent (4.3 Mg/yr) of these emissions were from valves. Forty-two percent (3.5 Mg/yr) of the emissions were from flanges. The remaining 7 percent (0.5 Mg/yr) were equipment leaks from mechanical pump seals (0.4 Mg/yr) and open-ended lines in service (0.1 Mg/yr). The four pressure relief devices were equipped with rupture discs. Preventative maintenance inspections are scheduled for all relief devices and critical instruments. Dow reported that a continuous air monitoring system is used, with 20 area sampling probes for leak detection. Equipment is monitored and inspected 24 hours per day by shift personnel.

TABLE 3-5. TOTAL PCE EMISSIONS FROM BY-PRODUCT FORMATION AND MISCELLANEOUS PRODUCTION USES

Plant/Location	1983 Perchloroethylene Emissions (Mg)							
	Process	Fugitive	Relief Devices	Storage	Handling	Equipment Openings	Secondary	Total (Mg)
Dow Chemical U.S.A. Midland, MI	60.5	111.3	-	0.2	0.05	0.8	-	172.8[a]
Dow Chemical U.S.A. Freeport, TX	6.5	41.7	-	0.1	-	0.045	0.0004	48.6[b]
Shell Oil Company Deer Park, TX	0.02	-	-	0.236	0.045	-	-	0.30
Borden Chemicals Geismar, LA	-	-	-	0.0004	-	-	-	0.0004
Georgia Gulf Plaquemine, LA	25.1	-	-	0.001	-	-	-	25.2
TOTAL	92.1	153.0	-	0.54	0.095	0.845	0.0004	246.9

[a] Total emissions from 3 processes.
[b] Total emissions from 2 processes.

TABLE 3-6. CURRENT CONTROLS AND ESTIMATED EMISSIONS AT FACILITIES PRODUCING PCE AS A BY-PRODUCT OR FOR MISCELLANEOUS PROCESSES

Company/Location	Type of Emission/ Source	Present Controls	Reported Control Efficiency (%)	Present PCE Emissions (Mg/yr)	Comments
Dow Chemical U.S.A./ Midland, MI (process #1)	Process Vents				
	• *	Scrubber	NA	38.9	
	• *	Scrubber	NA	0.004	
	Fugitive	None	N/A	10.2	
	Equip. Op.	None	N/A	0.1	60-75 openings in 1983
	Storage				
	• pressure vessel	None	N/A	0.1	750 gallons
Dow Chemical U.S.A./ Midland, MI (process #2)	Process Vents				
	• *	Scrubber	*	21.6	
	Fugitive	None	N/A	72.5	
	Storage				
	• pressure vessel	Vent condenser/ scrubber	95	0.006	9500 gallons
	• pressure vessel	Vent condenser/ scrubber	95	0.001	2500 gallons
	Equip. Openings	None	N/A	0.0009	300 openings
Dow Chemical U.S.A./ Midland, MI (process #3)	Process Vents				
	• storage tank	None	N/A	0.003	
	Fugitive	None	N/A	28.6	
	Storage Tanks				
	• pressure vessel	None	N/A	0.1	6500 gallons
	Equip. Openings	None	N/A	0.7	100 openings
	Handling/loading	None	N/A	0.002	
Dow Chemical U.S.A./ Freeport, TX (TCE process)	Fugitive	None	N/A	5.5	
	Storage	*	*	0.1	

TABLE 3-6 (CONCLUDED). CURRENT CONTROLS AND ESTIMATED EMISSIONS AT FACILITIES PRODUCING PCE AS A BY-PRODUCT OR FOR MISCELLANEOUS PROCESSES

Company/Location	Type of Emission/ Source	Present Controls	Reported Control Efficiency (%)	Present PCE Emissions (Mg/yr)	Comments
	Equip. Openings	None	N/A	0.045	20 openings in 1983
	Secondary				
	• *	*	*	0.0004	
Dow Chemical U.S.A./ Freeport, TX (confidential process)	Process Vent	*	*	6.5	
	Fugitive	None	N/A	36.2	
	Loading/Handling	None	N/A	0.1	
Borden Chemical/ Geismar, LA (EDC production)	Storage				
	• pressure vessel	Incineration	98[a]	0.0004	50,000 gallons, PCE is 0.05% of material stored in tank
Shell Oil Company/ Deer Park, TX (VCM production)	Process Vents				
	• column vents (2)	Incineration	98[a]	0.01	
	Storage				
	• fixed-roof tank (4)	Compression/ Incineration	98[a]	0.00005	376,000 gallons
	• fixed-roof tank	Compression/ Incineration	98[a]	0.00001	282,000 gallons
	• fixed-roof tank	Compression/ Incineration	98[a]	0.0004	424,000 gallons
	• fixed-roof tank	None	N/A	0.233	56,000 gallons
	Handling	None	N/A	0.001	Into tank trucks
Georgia Gulf/ Plaquemine, LA	Process Vents				
	• *	*	*	25.1	
	Storage				
	• *	*	*	0.01	

[a] Although the plant reported 99.99% control efficiency, only 98% is accepted when sampling data are not available. However, reported efficiencies were used to estimate emissions.

* The company considered this to be confidential information

NA = Not available

N/A = Not applicable

Approximately 1 percent (0.1 Mg/yr) of the PCE emissions were from equipment openings. There were 60 to 75 openings in PCE service in 1983.

Less than 1 percent (0.02 Mg/yr) of the emissions were from raw material storage according to AP-42 calculations for storage tanks. The PCE was stored in a 750-gallon pressure vessel. Even though State regulations do not control emissions from tanks under 40,000 gallons, pressure tanks are an accepted method of emissions control in Michigan for tanks with capacities greater than 40,000 gallons.

- Process #2 - The total PCE emitted from this process in 1983 was 95 Mg. Seventy-six percent (72.5 Mg/yr) of the emissions were fugitive emissions, which are not controlled by Federal or State regulations. Twenty-nine percent (20.1 Mg/yr) of the total fugitive emissions were from flanges. Valves and open-ended lines were the sources of 34 percent (24.5 Mg/yr) and 26 percent (18.9 Mg/yr) of the fugitive emissions, respectively. The remaining 11 percent (9 Mg/yr) of the PCE emissions were emitted from mechanical pump seals, pressure relief devices in gas service, sample connections, and open-ended lines in gas. Fugitive emission monitoring/control involves instrumentation designed to alarm at overflow or overpressure conditions. Annual preventative maintenance is performed on pressure relief devices and process equipment in PCE service.

There were seven pressure relief devices that discharged to control equipment (a scrubber). The estimated control device efficiency was 75 percent. This estimate was based on the ideal gas law and scrubber solubility. The emissions from these discharges were not reported by Dow.

Emissions from a process vent are controlled by a scrubber and totalled 21.6 Mg/yr. Dow indicated that this was a continuous vent stream of constant flowrate and composition. All other information was considered confidential by Dow. Michigan does not regulate VOC emissions from vent streams.

Less than 1 percent (0.007 Mg/yr) of the total PCE emissions were from raw material storage. Two pressure vessels with capacities of 9,500 and 2,500, respectively, were the sources of these emissions. Vent condensers and scrubbers control the tank emissions, achieving a 95 percent control efficiency. These tanks are too small to be regulated in Michigan.

Losses from equipment openings were less than 1 percent of the total PCE emissions (0.0009 Mg/yr). There were approximately 300 equipment openings in 1983.

- Process #3 - The total PCE emissions from this process in 1983 were 29.3 Mg. Ninety-seven percent (28.6 Mg/yr) of these emissions were fugitive emissions. The largest sources of fugitive emissions were valves, flanges, and open-end lines. Thirty-three percent (9.0 Mg/yr) of the fugitive emissions were from valves, 30 percent (8.0 Mg.yr) from flanges, 26 percent (7.0 Mg/yr) from open-end lines in liquid service. The other emission sources were mechanical pump seals (1.3 Mg/yr), pressure relief devices (0.9 Mg/yr), open-end lines in gas service (0.8 Mg/yr), and sample connections (0.2 Mg/yr). Routine equipment inspections are performed on the process.

One-hundred equipment openings resulted in 2 percent (0.7 Mg.yr) of the total PCE emissions in 1983. There are no State or Federal regulations for the control of these emissions.

PCE emissions from storage tanks were 0.3 percent (0.1 Mg/yr) of the total emissions. A 6,500-gallon pressure vessel was the source of emissions. There are no add-on control devices, but the tank is kept pressurized. This tank is smaller than the size cut-off (40,000 gallons) in Michigan.

The emissions from a small holding tank were approximately 0.01 percent (0.003 Mg/yr) of the total emissions. The holding tank is filled about 5 times annually. The tank only vents when it is filled. Duration of venting is about 30 minutes.

Loading and handling operations released less than 1 percent (0.002 Mg/yr) of the total PCE emissions. PCE was lost during the hose disconnection of the off-loading stage. The PCE was received in 50,000 lb quantities in tank trucks. Due to the vapor pressure cutoff limit of 1.5 psia, PCE is exempt from loading/unloading regulations in Michigan.

There were no secondary emissions from the disposal of a liquid waste stream. Dow reported that there were no emissions due to complete incineration at their facility.

Borden Chemical - Geismar, LA[7]

PCE is a by-product generated from the production of EDC at this facility. The only PCE emissions from the facility are from by-product storage. PCE was only 0.5 percent of the total composition stored in a 50,000-gallon pressure vessel. Approximately 0.004 Mg of PCE were emitted from this vessel. The tank contains various other chlorinated hydrocarbon impurities generated from the EDC process. These impurities are incinerated. Borden reported an incinerator destruction efficiency of 99.99 percent based on sampling data. PCE emissions from tanks of at least 40,000 gallons are regulated in Louisiana. According to Louisiana regulations, this pressure tank is an acceptable control device.

Shell Oil Company - Deer Park, TX[8]

PCE is produced as a by-product in the manufacturing of vinyl chloride monomer (VCM). All VC emissions from this facility must be controlled according to the requirements of the NESHAP for VC. The total PCE emissions from this process in 1983 was 0.24 Mg. Ninety-nine percent (0.236 Mg) of these emissions were from seven fixed-roof storage tanks. Ninety-six percent (0.233 Mg/yr) of the total emissions were from one 56,000-gallon tank which had no emissions control. PCE was only 1 to 3 percent of the total chemical composition in the tank. Four percent (0.001 Mg/yr) of the storage emissions were from the other six fixed-roof tanks ranging in size from 282,000 gallons to 424,000 gallons. Compression and incineration were the emission control methods, achieving an estimated 98 percent control efficiency. PCE accounted for 0.0035 to 0.005 percent of the total composition stored in each tank.

The small concentrations of PCE in these tanks compared to the concentrations in the uncontrolled tank suggests that these six tanks contain VC product and are, therefore, subject to the NESHAP.

Shell estimated that the total handling/loading emissions in 1983 were 0.045 Mg. The heavy ends from EDC distillation were transferred to tank trucks. The stream contained 1 to 3 percent PCE. No vapor recovery is used as the ends are loaded into tank trucks. Shell estimated that the total handling emissions were less than 0.045 Mg in 1983. The EDC process at the plant is most likely not covered by the VCM NESHAP. However, in Harris County, vapor recovery systems are required for the loading or unloading of all VOC with vapor pressure of 1.5 psia or greater at facilities with greater than 20,000 gallons or more throughput per day. The vapor pressure of PCE and the additional VOC in the stream probably did not exceed the cutoff of 1.5 psia.

Process vents on two incinerator stacks were the sources of less than 1 percent (0.01 Mg/yr) of the total PCE emissions. The incinerators destroy the impurities in the light and heavy ends recovered from the EDC distillation stage. Shell reported that there was less than 5 percent PCE in any equipment where PCE was used. However, no other information was provided concerning the fugitive emissions sources in PCE service. The company indicated that all flanges and valves on equipment in VC service are checked annually for fugitive emissions using a portable hydrocarbon detector. The vinyl chloride NESHAP requires that leaks from equipment in VC service must be minimized via formal leak detection and elimination (LD&E) program, designed by the operator and approved by the Administrator of EPA.

Shell did not indicate how many equipment openings occurred at the facility in 1983. They only reported that there were no equipment with greater than 10 percent PCE.

Dow Chemical U. S. A. - Freeport, TX[9]

PCE is produced as a by-product of the TCE process at this facility. The total PCE emissions from this process in 1983 were 5.6 Mg. Ninety-nine percent (5.5 Mg/yr) of these emissions were from equipment leaks. Thirty-eight percent (2.0 Mg/yr) of the fugitive emissions were from valves.

Eighteen percent (1.0 Mg/yr) of the emissions were from open-end lines and 16 percent (0.9 Mg/yr) were from sample connections. Mechanical pump seals and flanges are the sources of the remaining fugitive emissions, consisting of 15 percent (0.8 Mg/yr) and 3 percent (0.1 Mg/yr) of the total fugitive emissions, respectively. The TACB has recently promulgated regulations that will require a formal fugitive emissions monitoring program taking effect in 1987.

Twenty equipment openings were the sources of less than 1 percent (0.045 Mg/yr) of the total PCE emissions from this process. Equipment is drained of liquid which is recycled back into the system for reprocessing. After this initial draining, vapors are evacuated with a vacuum system to assure minimum exposure. Nitrogen is then purged through the equipment to vacuum the system to remove vapors.

Less than 1 percent (0.1 Mg/yr) of the total PCE emissions were from storage. All tank and emission control information was considered confidential by Dow.

Dow indicated that there were no PCE handling emissions in 1983. The PCE by-product is transported in railcars which are loaded through the dome of the car's dip tube. The cars are then vented to a scrubber to contain the vapors. Although the sampling data were not submitted by Dow, the company reported that the scrubber was 100 percent effective at controlling the PCE emissions.

Two sources of secondary emissions accounted for 0.5 percent (0.0004 Mg/yr) of the total PCE emissions from the process. These emissions were from the disposal of the bone char and calcium chloride waste streams by landfill.

Dow Chemical U. S. A. - Freeport, TX[9]

PCE was used in the production of another chemical at this facility. All information concerning the product and the process is considered confidential by Dow.

The total PCE emissions in 1983 were approximately 43 Mg. Fugitive emissions accounted for 85 percent (36.2 Mg/yr) of the total emissions. The largest source of fugitive emissions were valves, which accounted for

53 percent (19 Mg/yr) of the total fugitive emissions. Pressure relief devices and mechanical pump seals were each the sources of 13 percent (4.6 Mg/yr) of the total fugitive emissions. The remaining emissions were from flanges (7 Mg/yr) and sample connections (0.5 Mg/yr). The recently-promulgated regulations by the TACB were discussed in Section 2.2.1.2 of this report.

The process vent emissions were 14 percent (6.5 Mg/yr) of the total PCE emissions. All other information was considered confidential by Dow. There were no releases from pressure relief devices in 1983.

The PCE emissions from loading/handling operations and secondary sources were less than 1 percent (0.1 Mg/yr) of the total emissions. All other information was considered confidential by Dow.

Georgia Gulf - Plaquemine, LA[10]

PCE is an impurity formed in the production of EDC and VCM. The total emissions from this process were 25.2 Mg/yr. The largest source of PCE emissions is a process vent stream which emitted 99 percent (25.1 Mg/yr) of the total PCE emissions. All information concerning this stream was considered confidential by Georgia Gulf. The vinyl chloride NESHAP requires that all vent gases from process and storage vessels in VC service to be controlled to 10 parts per million (ppm) or less VC.

Less than 1 percent (0.001 Mg/yr) of the PCE emissions were emissions from storage. All information concerning storage tanks was considered confidential by Georgia Gulf. Emissions from this facility must be controlled by the vinyl chloride NESHAP, which requires that the concentration of VC in exhaust gases discharged to the atmosphere from storage tanks must not exceed 10 ppm.

3.4 REFERENCES

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4.0 DRY CLEANING INDUSTRY

Fifty-one percent of the total PCE produced in 1983 was consumed as a dry cleaning solvent. An estimated 26,000 dry cleaning facilities existed in the United States in 1978.[1] Due to the large number of these facilities, no attempt was made in this study to directly contact any of these facilities or to verify the exact number of facilities presently in operation. Emissions from dry cleaning operations were estimated in this study by obtaining the 1983 consumption of PCE in dry cleaning and using previous EPA studies to estimate the fraction of PCE consumed that is emitted to the atmosphere. It is estimated that in 1983 about 117,000 Mg of PCE were consumed by the dry cleaning industry of which about 50,000 Mg were emitted. The majority of the remaining PCE is recycled. The following sections present a brief discussion of the dry cleaning industry, cleaning operations, emission sources and levels, applicable control techniques, and regulatory requirements for the dry cleaning industry.

4.1 INDUSTRY DESCRIPTION

The dry cleaning industry can be divided into three sectors: coin-operated, commercial, and industrial dry cleaners. Seventy-one percent of the PCE used for dry cleaning is used by the commercial sector. The coin-operated and industrial sectors use 18 and 11 percent, respectively.[2]

4.1.1 Coin-Operated Cleaners

Coin-operated cleaners are small self-service facilities that are usually associated with neighborhood laundromats. They are either independently-owned and operated facilities or operated on a franchise basis. Available literature indicates that there were an estimated 11,804 coin-operated dry cleaning facilities using PCE in 1978.[1]

Only synthetic cleaning solvents (no petroleum solvents) are used at coin-operated facilities and PCE is the solvent of choice in 97.5 percent of the facilities.[1] All coin-operated machines are dry-to-dry units where the clothes are washed and dried in a single unit. Machine capacities at coin-operated cleaners range in size from 3.6 kg to 11.5 kg per load. A typical installation has two or three machines with annual throughput estimated at 9,050 kg.[1] The parameters for a typical coin-operated dry cleaner are shown in Table 4-1.

4.1.2 Commercial Cleaners

Commercial dry cleaners are typically small dry cleaning facilities offering nonself-service cleaning. Commercial dry cleaners are represented by small neighborhood shops that are independently owned ("Mom and Pop" operations), franchise shops offering general dry cleaning and laundry services, and specialty cleaners that handle leather and other fine goods.[1] There were an estimated 15,060 commercial cleaners using PCE in 1978.[1]

Seventy-three percent of the commercial sector uses PCE. The remaining commercial cleaners use either petroleum solvents (24 percent) or trichlorotrifluoroethane (3 percent). Most machines (75 percent) used in the commercial sector are transfer machines, where clothes are washed in one unit and then transferred to a separate unit to be dried.[1] Machine capacities range from 11 kg to 23 kg per load. A typical commercial facility has one dry cleaning system with an annual throughput of about 17,700 kg.[1] The parameters for a typical commercial dry cleaner are shown in Table 4-1.

4.1.3 Industrial Cleaners

Industrial dry cleaners are the largest dry cleaning plants. They are predominantly engaged in supplying rental services for items such as uniforms, mops, and mats to businesses, industries, and institutions.[1] Approximately 40 to 45 percent of all industrial laundry facilities have dry cleaning equipment and 50 percent of these use PCE. There were an estimated 334 industrial dry cleaners using PCE in 1978.[3]

A typical industrial dry cleaning facility has one dry cleaning system consisting of 250 kg per load capacity washer/extractor and three to six 38-kg capacity dryers. Annual throughput for facilities in this sector range from 240,000 to 700,000 kg and average 468,750 kg/year for a typical source.[1] The parameters for a typical industrial dry cleaning facility are shown in Table 4-1.

TABLE 4-1. PARAMETERS FOR TYPICAL DRY CLEANING FACILITIES, 1978

Industry Sector	Machine Capacity	# Machines per Plant	Throughput (kg clothes/yr)	Emission type	Annual Emissions (kg/year)
Coin-Operated	3.6 kg (8 lbs)	2	9,050	Process	908
				Fugitive[a]	52
Commercial	11-23 kg (25-50 lbs)	1	17,700	Process	1,078
				Fugitive	62
Industrial	113 kg (250 lbs)	1	470,000	Process	22,500
				Fugitive	1,300

[a] Fugitives also include losses from opening and closing dryers.

4.2 CLEANING PROCESS CHARACTERIZATION

The basic dry cleaning process is identical to those of ordinary laundering practices except that a solvent such as PCE is used instead of water. Three principle steps are involved in the process: (1) one (or more) solvent wash cycles; (2) physical extraction of excess solvent during a spin cycle; and (3) tumble drying.[1] These steps are the same for both transfer and dry-to-dry machines.

Because PCE is expensive, additional steps can be taken to ensure more economical plant operations. These steps, used at larger dry cleaning facilities, include solvent treatment by filtration, distillation, and charging. Solvent treatment allows for partial recovery and reuse of solvent.[4]

Filtration removes nonsoluble soils from used solvent. Filters may contain activated carbon to remove dye residue. The solids (called muck) are removed from the filters on a daily basis. Muck contains solvent that is recovered by distillation except in plants that use a disposable filter system. In these plants, the filters are drained and thrown away.[4]

Soluble nonvolatile residue also accumulates in the solvent. This residue, composed primarily of oils, fats, and greases, is not removed by filtration. A distillation process is used to remove this residue from the solvent.[4]

A small amount of water and detergent must be added to the solvent to remove water-soluble residue from fabric. This step is called charging and must be repeated after each distillation.[1]

4.3 EMISSION SOURCES

Dry cleaning systems have several sources of emissions. The major sources are the dryer and filter muck followed by the disposal of waste materials, and losses from liquid and vapor leaks.

In general, the emissions can be characterized as process or fugitive emissions. Process emissions include emissions from washers, dryers, stills, and muck cookers. Fugitive emissions include losses from pumps, valves, flanges, seals, storage vessels, chemical and water separators, and losses from handling of solvent and material.

4.4 EMISSION ESTIMATES

An estimated 49,740 Mg of PCE were emitted from the dry cleaning industry, accounting for 45 percent of the total PCE emissions in 1983. This estimate is based on the 1983 PCE consumption data and the fraction of PCE that is emitted per kg PCE consumed by the three sectors of the dry cleaning industry.

The HSIA indicated that in 1983, coin-operated dry cleaners used 20,960 Mg of PCE, commercial dry cleaners used 82,830 Mg, while industrial dry cleaners used 13,050 Mg.[2] Emission factors for a typical facility in each of the three dry cleaning sectors were obtained from the background information document (BID) for the proposed standards for PCE dry cleaners.[1] Since the emission factors are expressed in terms of kg PCE emitted/100 kg clothes cleaned, an estimate had to be made of the amount of clothes cleaned in 1983. This was done by using the ratio of PCE dry cleaning consumption in 1976[1] and consumption in 1983. The ratio was applied to the amount of clothes cleaned in 1976[1] to estimate the amount of clothes cleaned in 1983. This procedure was carried out individually for the coin-operated, commercial, and industrial dry cleaners. The appropriate emission factor (kg PCE emitted/kg clothes cleaned) was then applied to estimate 1983 emissions from each of the three dry cleaning sectors. Table 4-2 shows the variables used to calculate these emissions. It is estimated that in 1983 about 16,800 Mg of PCE were emitted by coin-operated dry cleaners, 25,000 Mg by commercial dry cleaners, and about 8,000 Mg by industrial dry cleaners.

Table 4-3 shows PCE emissions from coin-operated dry cleaners in each State. These emissions were estimated from the number of coin-operated dry cleaners in each state[5] and by assuming that the PCE emissions are divided equally between each coin-operated facility.

The number of commercial dry cleaners, broken down by the number of employees, were estimated in a previous EPA study.[5] Since it can be reasonably expected that a large facility (i.e., large number of employees) would use more dry cleaning solvent than a smaller facility, an "employee-weighted average" number of facilities was calculated for each State. The

TABLE 4-2. VARIABLES USED TO CALCULATE PCE EMISSIONS

	PCE Consumption 1976, Mg	PCE Consumption 1983, Mg	Clothes Cleaned 1976, kg	Clothes Cleaned 1983, kg	Emission Factor, kg PCE/100 kg clothes cleaned	1983 Emissions, Mg
Coin-Operated	29,951	20,961	47,021	32,907	15.7	16,767
Commercial	118,354	82,828	112,436	78,686	9.5	25,020
Industrial	18,652	13,053	19,398	13,572	10.4	7,949

TABLE 4-3. TOTAL 1983 PCE EMISSIONS FROM COIN-OPERATED DRY CLEANERS, BY STATE

State	# Plants, Percent of Total U. S. Facilities	Total 1983 Emissions (Mg)
Alabama	1.55	260.0
Alaska	0.12	20.1
Arizona	1.49	250.0
Arkansas	0.68	114.0
California	7.60	1,274.7
Colorado	1.60	268.3
Connecticut	0.93	156.0
Delaware	0.068	11.4
District of Columbia	0.72	120.7
Florida	5.04	845.3
Georgia	1.24	208.0
Hawaii	0.39	65.4
Idaho	0.23	38.6
Illinois	8.83	1,481.0
Indiana	4.02	674.2
Iowa	1.22	204.6
Kansas	1.32	221.4
Kentucky	1.21	202.9
Louisiana	0.96	161.0
Maine	0.18	30.2
Maryland	1.35	226.4
Massachusetts	2.31	387.4
Michigan	5.50	922.5
Minnesota	1.25	209.6
Mississippi	0.52	87.2
Missouri	2.49	417.6
Montana	0.20	33.5

TABLE 4-3 (CONCLUDED). TOTAL 1983 PCE EMISSIONS FROM COIN-OPERATED DRY CLEANERS, BY STATE

State	# Plants, Percent of Total U. S. Facilities	Total 1983 Emissions (Mg)
Nebraska	0.48	80.5
Nevada	0.35	58.7
New Hampshire	0.28	47.0
New Jersey	2.19	367.3
New Mexico	0.75	125.8
New York	10.16	1,704.0
North Carolina	1.51	253.2
North Dakota	0.12	20.1
Ohio	5.98	1,003.0
Oklahoma	1.78	298.5
Oregon	0.63	105.7
Pennsylvania	2.97	498.1
Rhode Island	0.62	104.0
South Carolina	0.52	87.2
South Dakota	0.19	31.9
Tennessee	2.56	429.4
Texas	10.08	1,690.6
Utah	0.36	60.4
Vermont	0.042	7.0
Virginia	1.78	298.5
Washington	1.23	206.3
West Virginia	0.39	65.4
Wisconsin	1.86	311.9
Wyoming	0.12	20.1
TOTAL		16,766.6

amount of PCE emissions in each State was estimated by allocating the total PCE emissions for commercial dry cleaners according to the "weighted average" number of facilities in each State. For example, consider the following commercial dry cleaning facilities in Alabama and Michigan, listed according to the number of employees:

State	Number of plants by size of operation (employees)				
	1 - 4	5 - 9	10 - 19	20 - 49	50+
Alabama	67	28	14	9	2
Michigan	169	92	51	30	4

- The mid-point of the number of employee range classification was then multiplied by the number of facilities in that classification.

  "Weighted Average" Facilities in:
  Alabama = (67)(2.5) + (28)(7) + (14)(14.5) + (9)(34.5) + (2)(51) = 979
  Michigan = (169)(2.5) + (92)(7) + (51)(14.5) + (30)(34.5) + (2)(51) = 3045

- The total number of "weighted average" facilities in the U.S. was similary calculated to be 65,267. The ratio of "weighted average" facilities in each state to the "weighted average" found in the country was used to calculate emissions. For example, PCE emissions from commercial dry cleaners in Alabama in 1983 were:

$$\frac{979}{65,267}\,(25,100\text{ Mg}) = 379\text{ Mg}$$

Table 4-4 shows the estimated emissions from commercial dry cleaners by State.

The exact location of each of the 334 industrial dry cleaners were identified in a previous EPA study.[3] It was assumed in this study that each industrial dry cleaner emits the same amount of PCE annually (i.e., 7,949 ÷ 334 = 23.8 Mg). Based on this assumption, PCE emissions were estimated for each state and are shown in Table 4-5.

TABLE 4-4. TOTAL 1983 PCE EMISSIONS FROM COMMERCIAL DRY CLEANERS, BY STATE

State	# Plants, Weighted Average By State (%)	Total 1983 Emissions (Mg)
Alabama	1.50	379.8
Alaska	0.002	0.5
Arizona	1.10	278.5
Arkansas	0.56	141.8
California	9.90	2,507.0
Colorado	1.50	379.8
Connecticut	1.80	455.8
Delaware	0.29	73.4
District of Columbia	1.10	278.5
Florida	3.50	886.3
Georgia	2.60	658.4
Hawaii	0.40	101.3
Idaho	0.16	40.5
Illinois	5.90	1,494.1
Indiana	2.20	557.1
Iowa	0.77	195.0
Kansas	0.67	169.7
Kentucky	1.2	303.9
Louisiana	1.4	354.5
Maine	0.31	78.5
Maryland	2.1	531.8
Massachusetts	3.4	861.0
Michigan	4.6	1,164.9
Minnesota	1.5	379.8
Mississippi	0.7	177.3
Missouri	1.7	430.5

TABLE 4-4 (CONCLUDED). TOTAL 1983 PCE EMISSIONS FROM COMMERCIAL DRY CLEANERS, BY STATE

State	# Plants, Percent of Total U. S. Facilities	Total 1983 Emissions (Mg)
Montana	0.19	48.1
Nebraska	0.68	172.2
Nevada	0.92	233.0
New Hampshire	0.18	45.6
New Jersey	3.00	759.7
New Mexico	0.36	91.2
New York	9.00	2,279.1
North Carolina	2.50	633.1
North Dakota	0.27	68.4
Ohio	5.60	1,418.1
Oklahoma	1.20	303.9
Oregon	0.54	136.7
Pennsylvania	4.90	1,240.8
Rhode Island	0.58	146.9
South Carolina	1.20	303.9
South Dakota	0.10	25.3
Tennessee	2.10	531.8
Texas	8.60	2,177.8
Utah	0.065	16.4
Vermont	0.03	7.6
Virginia	3.00	759.7
Washington	0.93	235.5
West Virginia	0.44	111.4
Wisconsin	1.50	379.8
Wyoming	0.059	14.9
TOTAL		25,020.6

TABLE 4-5. TOTAL 1983 PCE EMISSIONS FROM INDUSTRIAL DRY CLEANERS, BY STATE

State	Total 1983 Emissions (Mg)
Alabama	166.6
Arizona	47.6
Arkansas	23.8
California	809.2
Colorado	23.8
Connecticut	142.8
Delaware	23.8
District of Columbia	47.6
Florida	214.2
Georgia	238.0
Idaho	47.6
Illinois	928.2
Indiana	309.4
Iowa	23.8
Kansas	47.6
Kentucky	23.8
Louisiana	119.0
Maine	71.4
Maryland	119.0
Massachusetts	285.6
Michigan	238.0
Minnesota	95.2
Mississippi	47.6
Missouri	142.8
Nebraska	214.2
Nevada	47.6
New Hampshire	23.8
New Jersey	214.2

TABLE 4-5 (CONCLUDED). TOTAL 1983 PCE EMISSIONS FROM INDUSTRIAL DRY CLEANERS, BY STATE

State	Total 1983 Emissions (Mg)
New Mexico	23.8
New York	357.0
North Carolina	261.8
Ohio	499.8
Oklahoma	142.8
Pennsylvania	809.2
Rhode Island	23.8
South Carolina	166.6
South Dakota	47.6
Tennessee	238.0
Texas	214.2
Virginia	190.4
West Virginia	142.8
Wisconsin	95.2
TOTAL	7,949.2

4.5 CONTROL TECHNIQUES

PCE emissions from dry cleaners have historically been controlled to some extent for economic reasons even before the development of CTG regulations.[1] Solvent recovery dryers are used at most establishments. This practice allows the use of PCE to be as cost competitive as the cheaper petroleum solvents. Carbon adsorption is used at about 35 percent of all commercial facilities, 50 percent of all industrial facilities and 5 percent of all coin-operated facilities to capture solvent for recycle.

There are currently two methods of add-on control technology available for controlling PCE emissions at dry cleaners. These methods, carbon adsorption, and refrigeration/condensation, are used to control emissions from washers, dryers, stills, and muck cookers.

Carbon adsorption is the most common form of control for PCE. In this process, PCE-laden air is passed over activated carbon. Prior to the carbon reaching saturation, the air stream is diverted and the carbon is desorbed by passing steam through the adsorbent. Solvent that has been vaporized by the steam is then recovered downstream in a condenser, separated from the water, and then returned to the storage tank. Carbon adsorption can be used to achieve 100 ppm or less outlet concentration.[4]

Refrigeration/condensation systems provide an alternative to carbon adsorption systems. The refrigerated condenser is normally operated as a closed system, as opposed to the carbon adsorber that is exhausted to the atmosphere. In the refrigeration condensation process, the solvent-laden air is cooled below the dew point of the solvent causing it to condense and drain into the water separator. The air thus is stripped of solvent and recirculated to the air inlet of the dry cleaning system. Recovered solvent from the water separator is then fed to storage. Refrigeration units, however, are not capable of controlling emissions from the variety of sources that can be ducted to a carbon adsorber.[4]

Fugitive PCE emissions are difficult to quantify and occur at many different points of the dry cleaning process. Significant control of fugitive PCE emissions can be gained through the use of good housekeeping practices. These practices include maintenance of equipment, proper operation of equipment, proper storage and disposal of waste solvent and residue, proper storage of solvent, and avoiding spills. Emission sources that can be controlled in this manner are:

- Equipment Maintenance (tighten loose connections or replace defective equipment)
  - Hose connections
  - Door gaskets
  - Filter gaskets
  - Pump seals
  - Divertor valves
  - Air and exhaust ducts
  - Inefficient extraction due to loose belts
  - Equipment valves
- Proper Equipment Operation
  - Water separator loss
  - Filter sludge loss
  - Door losses (open doors only when necessary and only for short duration)
  - Extraction losses (overloading or underloading dryer hinders efficient extraction)
  - Transfer losses
  - Fabric loadout losses due to incomplete drying
  - Inefficient capture systems (build-up of lint in filters and on fan and condenser surfaces adversely affects solvent capture and recovery)
- Proper Storage and Disposal of Solvent and Waste Products
  - Cartridge filters
  - Saturated lint
  - Sludge
  - Solvent storage

4.6 REGULATORY REQUIREMENTS

There are no Federal regulations that require control of PCE emissions from dry cleaning. However, EPA has developed RACT guidelines which have been adopted by 23 States. Two additional States plus the District of Columbia have general VOC regulations concerning the use of photochemically reactive solvents. A summary of State regulations appears in Appendix A.

The six States with the highest PCE emissions from dry cleaning are New York, Ohio, Pennsylvania, California, Illinois, and Texas. These States together account for an estimated 45 percent of the total dry cleaning emissions of PCE. All of these States, except New York, have adopted EPA-approved RACT regulations for dry cleaning. New York's RACT regulations are currently being reviewed by EPA.

4.7 REFERENCES

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5. Mura, S. J., B. E. Suta, and S. S. Lee (SRI). Assessment of Human Exposures to Atmospheric Perchloroethylene. Prepared for the U. S. Environmental Protection Agency. Research Triangle Park, N. C. (Contract No. 68-02-2835). January 1979. 66 pp.

5.0 SOLVENT DEGREASING OPERATIONS

Fifteen percent (35,000 Mg) of the total PCE produced in 1983 was consumed as a solvent for degreasing operations. PCE was used as a solvent for degreasing in five manufacturing industries. Due to the large number of degreasing facilities in these industries, no attempt was made in this study to directly contact any degreasing facilities or to verify the exact number of facilities presently in operation. Emissions from degreasing operations were estimated in this study by obtaining the 1983 consumption of PCE for each and applying it to an emission factor derived for degreasing operations. It is estimated that in 1983, about 35,000 Mg of PCE were consumed in degreasing operations of which about 33,000 Mg were emitted. The following sections present a brief discussion of the types of degreasers, emissions, emissions control, and estimates of emissions from degreasing operations in 1983.

5.1 INDUSTRY DESCRIPTION

Degreasing is an integral part of many industrial categories such as automobile manufacturing, electronics, furniture manufacturing, appliance manufacturing, textiles, paper, plastics, and glass manufacturing. It is a process that is used when the surface of a part must be cleaned of all grease, metal chips, grit, fibers, abrasives, or other debris prior to painting, plating, or assembly. Various solvents, including petroleum distillates, chlorinated hydrocarbons, ketones, and alcohols are used either alone or together in degreasing operations.[1] Fifteen percent (35,060 Mg) of 1983 PCE production volume was used for solvent degreasing. Five major industry groups used PCE in degreasing operations. These are furniture and fixtures, fabricated metal products, electric and electronic equipment, transportation equipment, and miscellaneous industries.[2]

5.2 DEGREASING EQUIPMENT

There are three basic types of degreasing machines: cold cleaners, open top vapor degreasers, and conveyorized degreasers. Cold cleaners are usually the simplest and least expensive type. They consist of a tank of solvent with a cover for nonuse periods. More sophisticated cold cleaners have solvent sumps, spray nozzels, drains, and automatic controls. In the basic cold cleaning process, soiled objects are dipped into the solvent bath until the soils are dissolved from the surface. The cleaning process can be enhanced by agitating the solvent, brushing, or spraying. Solvents are usually used at room temperature, although, in some processes they may be heated (but not above the boiling point of the solvent).[1]

Open top vapor degreasers similar in configuration to cold cleaners clean as internally generated solvent vapors condense on relatively cold parts. They consist of tanks equipped with heating and cooling systems. The heating coils on the inside bottom of the tank boil the solvent, thereby generating the vapors needed for cleaning. Cooling coils located near the top and on the inside perimeter of the tank condense solvent vapors preventing them from diffusing out of the tank. Thus a controlled vapor zone is created within the tank. Soiled parts are lowered into the vapor zone where solvent condenses on their surfaces and dissolves the soils. When condensation ceases, the cleaned objects are withdrawn. Only halogenated solvents are used for vapor degreasing because they are nonflammable and because their heavy vapors can be easily contained within the machine.[1]

Conveyorized degreasers feature automated conveying systems for continuous cleaning of parts. Conveyorized degreasers clean by either the cold solvent process or the vaporized solvent process. While these units tend to be the largest degreasers, they are enclosed systems and actually produce less emissions per part cleaned than other types of degreasers.[1]

5.3 EMISSIONS FROM DEGREASING OPERATIONS

National emission estimates for degreasing operations were calculated from 1983 PCE consumption data provided by the HSIA. The consumption data were used in conjunction with emission factors generated from available literature to estimate nationwide emissions.[1] A brief description of the estimating procedure follows.

Available data indicate that 24 percent of all PCE consumed in degreasing operations is used in cold cleaning while about 76 percent is used in vapor degreasing.[1] Previous EPA studies estimated that for every kg of a solvent used in cold degreasing, 0.43 kg are emitted. The corresponding emission factors for open top vapor degreasing is 0.78 kg/kg consumed and 0.85 kg/kg consumed for conveyorized degreasing.[3] Assuming that vapor degreasing use of PCE is divided equally between open top and conveyorized degreasing processes, a weighted average emission factor of 0.72 kg/kg PCE consumed was calculated. It was assumed that the remaining 0.28 kg/kg PCE consumed would be recycled.

Based on information from solvent recyclers,[4] it was estimated that about 75 percent of all recycled solvent from degreasing (0.28 kg/kg PCE consumed) is recovered and reused. Therefore, total PCE consumption by a degreaser equals consumption of fresh solvent plus consumption of recycled solvent. As before, 0.72 kg/kg of the recycled solvent is emitted. Taking into account the emission of recycled solvent, it is estimated that for every kg of fresh PCE used in degreasing, 0.92 kg is emitted. Appendix C presents the details of these material balance calculations.

The total 1983 PCE emissions by each of the five industries using the chemical in degreasing operations were estimated by applying the 0.92 kg factor to the 1983 PCE consumption figure. Table 5-1 shows the estimated PCE emissions from degreasing operations in these industries.

Emissions were also estimated for each State in the U. S. The total number of employees in each of the five industries was estimated from U. S. Department of Commerce data.[5] The PCE emissions were estimated by assuming that emissions are proportional to the fraction of employees for a given industry in each State. For example, consider the emissions in Illinois from the fabricated products manufacturing industry (SIC 34):

- Fabricated products manufacturing consumption of PCE in 1983 = 14,976 Mg.

TABLE 5-1. 1983 PCE EMISSIONS FROM DEGREASING OPERATIONS, BY INDUSTRY

Industry	Emissions (Mg/yr)
Furniture and Fixtures	170
Fabricated Products	14,000
Electrical and Electronic Equipment	2,500
Transportation Equipment	10,300
Miscellaneous Manufacturing Industries	5,700
TOTAL	33,000

- $14{,}976 \text{ Mg} \times 0.92 \dfrac{\text{Mg emitted}}{\text{Mg consumed}} = 13{,}778 \text{ Mg emitted.}$
- The number of employees within the fabricated products manufacturing industry for Illinois = 119,005.
- Total number of employees within the fabricated products manufacturing industry = 1,497,989.
- $\text{Illinois emissions} = 13{,}778 \times \dfrac{119{,}005}{1{,}497{,}989} = 1{,}100 \text{ Mg}$

This procedure was followed for each industry identified to use PCE in degreasing operations. The results are presented for each State in Table 5-2.

5.4 EMISSIONS CONTROL

Control methods specified in the BID's for both RACT and NSPS standards are summarized in Table 5-3.[1,6] These methods include add-on equipment as well as improved work practices.

Add-on equipment for control of degreaser emissions can be as simple as adding covers to equipment openings, increasing freeboard area, adding freeboard chillers, and providing part drainage racks. These devices limit evaporation losses from solvent baths and solvent carry-out. More sophisticated control techniques include carbon adsorption to recover solvent vapors.

Work practices can be improved to limit solvent emissions from degreasing. These improvements, characterized by practices that reduce solvent exposure to the atmosphere, include: keep degreaser covers closed, fully drain parts prior to removal from degreaser, maintain moderate conveyor speeds, and keep ventilation rates moderate.

5.5 REGULATORY REQUIREMENTS

The EPA has approved RACT guidelines for solvent degreasing operations that have been adopted by 32 States and the District of Columbia. The 10 States that have the highest estimated emissions of PCE from solvent degreasing, California; Connecticut; Illinois; Indiana; Michigan; New York; New Jersey; Ohio; Pennsylvania; and Texas, have all adopted EPA-approved RACT. These 10 States account for about 61 percent of total degreasing emissions of PCE. In addition, EPA has proposed (but not promulgated) an NSPS that would control emissions from new solvent degreasers.

TABLE 5-2. 1983 PERCHLOROETHYLENE EMISSIONS FROM DEGREASING OPERATIONS, BY STATE

State	Emissions (Mg)	State	Emissions (Mg)
Alabama	447.5	Montana	9.8
Alaska	1.9	Nebraska	117.7
Arizona	286.4	Nevada	46.6
Arkansas	263.1	New Hampshire	124.9
California	4086.0	New Jersey	1058.7
Colorado	327.2	New Mexico	42.0
Connecticut	1184.1	New York	2090.9
Delaware	64.8	North Carolina	614.4
District of Columbia	5.1	North Dakota	16.2
Florida	772.9	Ohio	2405.8
Georgia	575.9	Oklahoma	376.2
Hawaii	20.6	Oregon	227.6
Idaho	22.5	Pennsylvania	1734.4
Illinois	1953.2	Puerto Rico	143.3
Indiana	1148.3	Rhode Island	539.1
Iowa	323.6	South Carolina	258.1
Kansas	399.1	South Dakota	19.1
Kentucky	353.4	Tennessee	639.4
Louisiana	388.1	Texas	1786.0
Maine	120.3	Utah	170.8
Maryland	293.3	Vermont	80.3
Massachusetts	1039.0	Virginia	497.9
Michigan	2553.9	Washington	706.0
Minnesota	488.1	West Virginia	88.9
Mississippi	336.6	Wisconsin	824.0
Missouri	840.1	Wyoming	2.7
		TOTAL	32,915.8

TABLE 5-3. CONTROL TECHNIQUES FOR DEGREASERS

Degreaser Type	Control Devices	Operating Practices
Cold Cleaners	Cover for tank Parts drainage rack Raised freeboard[a] Incinerator Carbon adsorber	Keep cover closed when degreaser not in use Fully drain cleaned parts
Vapor Degreasers	Cover for tank Freeboard chiller[b] Raised freeboard Incinerator Carbon adsorber	Keep cover closed when degreaser not in use Fully drain cleaned parts Move parts slowly into and out of degreaser
Conveyorized Degreasers	Port Covers Freeboard chillers Carbon adsorbers	Maintain conveyor at moderate speed Keep exhaust ventilation rates moderate

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[a] Freeboard is the distance from the liquid solvent surface or top of the vapor to the lip of the tank. "Raised freeboard" is a physical extension of the freeboard to reduce drafts, and thereby solvent evaporation, within the degreaser.

[b] Additional cooling coils above the primary coils to further inhibit the diffusion of solvent vapors to the atmosphere.

5.6 REFERENCES

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2. Letter from Morgan, D.L., Cleary, Gottlieb, Steen, and Hamilton, to Rosensteel, R.E., EPA. March 1, 1985. HSIA data on perchloroethylene production and consumption.

3. Hoogheem, T.J., D.A. Horn, T.W. Hughes, and P.J. Marn (Monsanto Research Corporation). Source Assessment: Solvent Evaporation - Degreasing Operations. Prepared for U.S. Environmental Protection Agency. Cincinnati, OH. Publication No. EPA-600/2-79-019f. August 1979. 133 p.

4. Telecon. Pandullo, R.F., Radian Corporation, with Pokorng, J., Baron-Blakeslee, Inc. March 19, 1985. General information on solvent recycling.

5. Bureau of the Census. County Business Patterns 1982. U.S. Department of Commerce. Washington, D.C. Publication No. CBP-82. October 1984.

6. GCA Corporation. Organic Solvent Cleaners - Background Information for Proposed Standards. Prepared for U.S. Environmental Protection Agency. Research Triangle Park, N.C. Publication No. EPA-450/2-78-045a. October 1979. 282 p.

6.0 DISTRIBUTION FACILITIES

Approximately 25 to 30 percent of total PCE production sold is used in the production of CFC's. Generally, sales of PCE to CFC producers are made directly. The remaining 70 to 75 percent of PCE is used in applications such as dry cleaning and solvent degreasing at numerous facilities across the country. Most of the PCE production in these applications reach the consumers through chemical distributors. There are an estimated 300 chemical distributors handling chlorinated solvents. Table 6-1 presents the three largest PCE distributors. These distributors represent approximately 20 percent of total PCE sold through distributors. In general, distributors maintain as few as three to as many as 65 regional distribution facilities spread out across the nation. One estimate places the number of regional distribution facilities at 500 nationwide.[2] Each district distributor receives chemicals directly from the producer by tank truck or railcar. Transportation is provided by the distributor. The received chemicals are stored by district distributors in 8,000 to 20,000 gallon fixed-roof storage tanks. The storage tanks used by district distributors include vertical, horizontal, and underground tanks. Turnover times for storage tanks typically range from 2 weeks to a little over a month. The exact number of distributors and distribution facilities that handle PCE is not known, however, it is estimated that there are 270 PCE storage tanks owned by distributors, the majority of which are fixed-roof tanks. The procedure used to estimate the number of tanks is given in Appendix D.

6.1 EMISSIONS FROM DISTRIBUTION FACILITIES

Emissions from distribution facilities can be categorized as two types, storage and handling. Storage emissions include breathing and working losses from tanks. Handling emissions result from vapor displacement when drums and tank trucks are filled.

TABLE 6-1. SUMMARY OF MAJOR PERCHLOROETHYLENE DISTRIBUTORS

Company	Number of Storage Facilities	Number of PCE Storage Tanks	Typical Size (gal)	Typical Turnover
Ashland[1]	61	37	8,000	3 wks - 1 mo
McKesson[2]	63	6	10,000	N/A
Chem-Central[3]	31	10	10,000	1 mo

Storage and handling emissions of PCE from distribution facilities were estimated using AP-42 emission factors[4] and data supplied by the major distributors. The details of those calculations are presented in Appendix D. It is estimated that approximately 50 Mg of PCE were emitted in 1983 from distribution facilities. Storage emissions accounted for 27 Mg, while handling emissions were about 23 Mg.

6.2 REGULATORY REQUIREMENTS

There are currently no State or Federal regulations affecting PCE distribution facilities. Most States have regulations for storage and handling of volatile organic liquids, however, PCE is exempted from these regulations due to its low vapor pressure. The vapor pressure cutoff for most State regulations is 1.5 psia under actual storage conditions. The vapor pressure for PCE is 0.3 psia.

6.3 REFERENCES

1. Telecon. Sterett, R., Ashland Chemical Company, with Howle, R. H., Radian Corporation. February 7, 1985. Conversation on storage of chlorinated solvents.

2. Telecon. Eisner, D., McKesson Chemical Company, with Howle, R. H., Radian Corporation. February 7, 1985. Conversation concerning storage of chlorinated solvents.

3. Telecon. Trice, L., Chem-Central, with Howle, R. H., Radian Corporation. February 8, 1985. Conversation concerning storage of chlorinated solvents.

4. U. S. Environmental Protection Agency. Compilation of Air Pollutant Emission Factors. Supplement 7. Research Triangle Park, North Carolina. Publication No. AP-42. August 1977.

7.0 MISCELLANEOUS USES OF PERCHLOROETHYLENE

Approximately 21,000 Mg of PCE were used in miscellaneous applications in 1983. These miscellaneous uses include the manufacture of: (1) adhesives, (2) aerosols, (3) paints and coatings; and (4) grain fumigant.[1,2] In its use in the manufacture of adhesives and paints and coatings, PCE acts as a general solvent carrier.[3] In the production of aerosols PCE has been used as a solvent and a carrier.[4] Another use of PCE has been as a grain fumigant, however, one source indicates that it is no longer approved for this use.[2,5]

7.1 EMISSION ESTIMATES

Table 7-1 summarizes the 1983 consumption and emissions of PCE from miscellaneous uses. It is assumed that 100 percent of PCE used in these applications is emitted to the atmosphere. The known miscellaneous uses are in consumer products that result in eventual emissions of PCE. The remaining unidentified uses are assumed to be in similar consumer applications. Geographically, these emissions can be expected to correlate with the general population in the country.

TABLE 7-1. MISCELLANEOUS USES OF PERCHLOROETHYLENE IN 1983[1]

Use	Consumption/Emissions (Mg/yr)
Adhesives	2,800
Aerosols	2,500
Paints & Coatings	1,700
Unidentified	13,700
Total	20,700

7.2 REFERENCES

1. Letter from Morgan, D. L., Cleary, Gottlieb, Steen, and Hamilton, to Rosensteel, R. E., EPA. March 1, 1985. HSIA data on perchloroethylene production and consumption.

2. Packer, K. (ed.). Nonogen Index - A Dictionary of Pesticides and Chemical Pollutants. Freedom, California. Nanogens International. December 1980. p. 97.

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5. Meister, R. T., et al (eds.). Farm Chemicals Handbook. Willoughby, Ohio. Meister Publishing Company. 1984. p. C-223.

8.0 PUBLICLY OWNED TREATMENT WORKS

8.1 EMISSION ESTIMATES

Recent EPA studies have estimated emissions of PCE from POTWs. The source of these emissions is considered to be industrial discharges of waste streams containing PCE. The studies have estimated that about 2,000 Mg of PCE are emitted annually from POTWs. These emission estimates were presented for about 900 counties. Table 8-1 presents the emissions for the 10 highest PCE emitting counties. These 10 counties account for about 35 percent of total PCE emissions from POTWs.

TABLE 8-1. PCE EMISSION ESTIMATES FROM POTWs IN THE 10 HIGHEST-EMITTING COUNTIES

County	Emissions (Mg)
Wayne, Michigan	230.3
St. Louis City, Missouri	74.9
Los Angeles, California	73.8
Cook, Illinois	67.8
Queens, New York	65.9
Harris, Texas	49.1
Jefferson, Texas	41.1
Hamilton, Tennessee	33.8
Erie, New York	30.5
Hampden, Massachusetts	30.2
Total	697.4

8.2 REFERENCES

1. Memorandum and attachments from Lahre, T., EPA:AMTB, to Southerland, J. H., EPA:AMTB. December 5, 1983. Initial look at available emissions data on POTWs.

APPENDIX A

METHODS USED FOR ESTIMATING STORAGE TANK AND FUGITIVE EMISSIONS

APPENDIX A: METHODS USED FOR ESTIMATING STORAGE TANKS AND FUGITIVE EMISSIONS

A.1 EMISSION FACTORS FOR FIXED-ROOF STORAGE TANKS

A.1.1 Emission Equations

The major types of emissions from fixed-roof storage tanks are breathing and working losses. Emission equations for breathing and working losses from storage tanks were developed in EPA Publication No. AP-42. The equations used in estimating emissions rates for fixed-roof tanks storing VOL are:

- $L_T = L_B + L_W$
- $L_B = 1.02 \times 10^{-5} M_v \left(\frac{P}{14.7-P}\right)^{0.68} D^{1.73} H^{0.51} T^{0.5} F_p C K_c$
- $L_W = 1.09 \times 10^{-8} M_v P V N K_n K_c$

where, L_T = total loss (Mg/yr)

L_B = breathing loss (Mg/yr)

L_W = working loss (Mg/yr)

A.1.2 Parameter Values and Assumptions

The following PCE physical property values, plant-specific information, and engineering assumptions were used to estimate the emission losses:

M_v = molecular weight of product vapor (lb/lb mole); for PCE, M_v = 165.82

P = true vapor pressure of product, 0.3 psia

D = tank diameter (ft); dependent upon plant-specific information.

C = tank diameter factor (dimensionless):

for diameter $\geq$ 30 feet, C = 1

for diameter < 30 feet, $C = 0.0771 D - 0.0013(D)^2 - 0.1334$

V = tank capacity (gal); dependent upon plant-specific information

N = number of turnovers per year (dimensionless); dependent upon plant-specific information

T = average diurnal temperature change in °F; 20°F was assumed for the storage tanks at these facilities

F_p = paint factor (dimensionless); the storage tanks were assumed to be in good condition and painted white; therefore, $F_p = 1$ (see Table A-1)

TABLE A-1. PAINT FACTORS FOR FIXED-ROOF TANKS

Tank Color		Paint factors (F_p) Paint condition	
Roof	Shell	Good	Poor
White	White	1.00	1.15
Aluminum (specular)	White	1.04	1.18
White	Aluminum (specular)	1.16	1.24
Aluminum (specular)	Aluminum (specular)	1.20	1.29
White	Aluminum (diffuse)	1.30	1.38
Aluminum (diffuse)	Aluminum (diffuse)	1.39	1.46
White	Gray	1.30	1.38
Light gray	Light gray	1.33	1.44
Medium gray	Medium gray	1.40	1.58

H = average vapor space height (ft): used tank-specific values or an assumed value of one-half the tank height (H/2)

K_c = product factor (dimensionless) = 1.0 for VOL

K_n = turnover factor (dimensionless); dependent upon plant-specific information

for turnovers > 36, $K_n = \frac{180 + N}{6N}$

for turnovers $\leq$ 36, $K_n = 1$

A.1.3 Sample Calculation

The following sample calculation is provided to demonstrate the evaluation of emissions from a typical fixed-roof storage tank containing PCE. For the general equations,

$$L_T = L_w + L_B$$

$$L_B = 1.02 \times 10^{-5}\ M_v \left(\frac{P}{14.7-P}\right)^{0.68} D^{1.73}\ H^{0.51}\ T^{0.5}\ F_p C K_C$$

$$L_w = 1.09 \times 10^{-8}\ M_v\ PVNK_n K_C$$

where, M_v = 165.82

P = 0.3 psia

D = 37 ft

C = 1

V = 233,000 gallons

N = 10

T = 20°F

F_p = 1.0

H = 14 ft

K_C = 1.0

K_n = 1

The emissions from this storage tank are:

$$L_B = 1.02 \times 10^{-5}\ (165.82)\left(\frac{0.3}{14.7-0.3}\right)^{0.68} (37)^{1.73}(14)^{0.51}(20)^{0.5}(1)(1)(1)$$

$$= 1.075 \text{ Mg/yr}$$

$$L_w = 1.09 \times 10^{-8}\ (165.82)(0.3)(233{,}000)(10)(1)(1)$$

$$= 1.263 \text{ Mg/yr}$$

$$L_T = 1.075 \text{ Mg/yr} + 1.263 \text{ Mg/yr} = 2.34 \text{ Mg/yr}$$

A.2 EMISSION FACTORS FOR INTERNAL FLOATING ROOF TANKS

A.2.1 Emission Equations

Emissions from internal floating roof tanks can be estimated from the following equations: (Note that these equations apply only to freely vented internal floating roof tanks.)

- $L_T = L_w + L_r + L_f + L_d$

where, L_T = the total loss (Mg/yr)

L_w = the working loss (Mg/yr) $\frac{(0.943)\ Q\ C\ W_l}{D}\ [1 + (\ \frac{N_c\ F_c}{D}\ )/2205$

where, D = tank diameter (ft)

N_c = number of columns (dimensionless)

F_c = effective column diameter (ft); 1.0 assumed

L_r = the rim seal loss (Mg/yr) $= (K_r D)\ P^*\ M_v\ K_C/2205$

L_f = the fitting loss (Mg/yr) $= (F_f)\ P^*\ M_v\ K_C/2205$

L_d = the deck seam loss (Mg/yr) $= (F_d\ K_d\ D^2)\ P^*\ M_v\ K_C/2205$

A.2.2 Parameter Values and Assumptions

The assumptions and values used to calculate emissions from internal floating roof tanks are:

Q = product average throughput (bbl/yr); tank capacity (bbl/turnover) x turnovers/yr; dependent upon plant-specific information

C = product withdrawal clingage factor ($bbl/10^3 ft^2$); use 0.0015 $bbl/10^3 ft^2$ for VOL in a welded steel tank with light rust (0.0075 for dense rust)

W_L = density of product (lb/gal); for PCE, 13.5 lb/gal

D = tank diameter (ft)

N_c = number of columns (dimensionless); (see Table A-2)

TABLE A-2. TYPICAL NUMBER OF COLUMNS AS A FUNCTION OF TANK DIAMETERS

Tank Diameter Range D (ft)	Typical Number Columns, N_c
$0 < D \leq 85$	1
$85 < D \leq 100$	6
$100 < D \leq 120$	7
$120 < D \leq 135$	8
$135 < D \leq 150$	9
$150 < D \leq 170$	16
$170 < D \leq 190$	19
$190 < D \leq 220$	22
$220 < D \leq 235$	31
$235 < D \leq 270$	37
$270 < D \leq 275$	43
$275 < D \leq 290$	49
$290 < D \leq 330$	61
$330 < D \leq 360$	71
$360 < D \leq 400$	81

F_c = effective column diameter (ft); 1.0 assumed

D = the tank diameter (ft); dependent upon plant-specific information

M_v = the average molecular weight of the product vapor (lb/lb mole). For PCE, $M_v = 165.82$

K_C = the product factor (dimensionless) = 1.0 for VOL

2205 = constant (lb/Mg)

P^* = the vapor pressure function (dimensionless)

$$P^* = 0.68\ P/((1 + 1 - 0.068\ P)^{0.5})^2)$$

P = the true vapor pressure of the material stored (0.3 psia for PCE)

K_r = the rim seal loss factor (lb mole/ft yr) that for an average fitting seal is as follows:

Seal system description	K_r (lb mole/ft yr)
Vapor-mounted primary seal only	6.7
Liquid-mounted primary seal only	3.0
Vapor-mounted primary seal plus secondary seal	2.5
Liquid-mounted primary seal plus secondary seal	1.6

F_f = the total deck fitting loss factor (lb mole/yr)

$$= \sum_{i=1}^{n} (N_{f_i}\ K_{f_i}) = [(N_{f_1}\ K_{f_1}) + (N_{f_2}\ K_{f_2}) + \ldots + (N_{f_n}\ K_{f_n})]$$

where, N_{f_i} = number of fittings of a particular type (dimensionless). N_{f_i} is determined for the specific tank or estimated from Tables A-2 and A-3. The values used for these emissions estimates are designated by *.

K_{f_i} = deck fitting loss factor for a particular type fitting (lb mole/yr). K_{f_i} is determined for each fitting type from Table A-3. The values used for these emissions estimates are designated by *.

Table A-3. SUMMARY OF DECK FITTING LOSS FACTORS (K_f) AND TYPICAL NUMBER OF FITTINGS (N_f)

Deck fitting type	Deck fitting loss factor, K_f (lbmole/yr)	Typical number of fittings, (N_f)
1. Access Hatch		1
a. Bolted cover, gasketed	1.6	
b. Unbolted cover, gasketed	11 *	
c. Unbolted cover, ungasketed	25	
2. Automatic Gauge Float Well		1
a. Bolted cover, gasketed	5.1	
b. Unbolted cover, gasketed	15 *	
c. Unbolted cover, ungasketed	28	
3. Column Well		(see Table A-2)
a. Built-up column-sliding cover, gasketed	33	
b. Built-up column-sliding cover, ungasketed	47	
c. Pipe column-flexible fabric sleeve seal	10	
d. Pipe column-sliding cover, gasketed	19 *	
e. Pipe column-sliding cover, ungasketed	32	
4. Ladder Well		1
a. Sliding cover, gasketed	56 *	
b. Sliding cover, ungasketed	76	
5. Roof Leg or Hanger Well		$(5 + \frac{D}{10} + \frac{D^2}{600})$[a]
a. Adjustable	7.9 *	
b. Fixed	0	
6. Sample Pipe or Well		1
a. Slotted pipe-sliding cover, gasketed	44 *	
b. Slotted pipe-sliding cover, ungasketed	57	
c. Sample well-slit fabric seal, 10% open area	12	
7. Stub Drain , 1-inch diameter	1.2 *	$(\frac{D^2}{125})$[b]
8. Vacuum Breaker		1
a. Weighted mechanical actuation, gasketed	0.7 *	
b. Weighted mechanical actuation, ungasketed	0.9	

[a] Not used on welded, contact internal floating decks.
[b] D = tank diameter (ft).

SOURCE: U. S. Environmental Protection Agency. VOC Emissions from Volatile Organic Liquid Storage Tanks - Background Information for Proposed Standards. Research Triangle Park, North Carolina. Publication No. EPA-450/3-81-003a. July 1984. 252 pp.

n = number of different types of fittings (dimensionless)

F_d = the deck seam length factor (ft/ft^2)

= 0.15, for a deck constructed from continuous metal sheets with a 7 ft spacing between seams

= 0.33, for a deck constructed from rectangular panels 5 ft by 7.5 ft

= 0.20, an approximate value for use when no construction details are known

K_d = the deck seam loss factor (lb mole/ft yr)

= 0.34 for nonwelded roofs

= 0 for welded decks

A.2.3 Sample Calculation

The following sample calculation is provided to demonstrate the evaluation of emissions from a typical storage tank with an internal floating roof containing PCE. For the general equations,

$$L_T = L_W + L_r + L_f + L_d$$

$$L_W = \frac{(0.943)QCW_L}{D} \left[1 + \frac{N_c F_c}{D} /2205 \right]$$

$$L_r = (K_r D)\ P^*\ M_v\ K_c/2205$$

$$L_f = (F_f)\ P^*\ M_v\ K_c/2205$$

$$L_D = (F_d K_d D^2)\ P^*\ M_v\ K_c/2205$$

where, M_v = 165.82 lb/lb mole

P^* = 0.0515

Q = 500,000 bbl/yr

C = 0.0015

W_L = 13.5 lb/gal

D = 30 ft

N_c = 1

F_c = 1.0

K_r = 6.7 lb mole/ft yr

K_c = 1.0

F_f = 242 lb mole yr

F_d = 0.20

K_d = 0

The emissions from this storage tank are:

$$L_W = \frac{(0.943)(500{,}000)(0.0015)(13.5)}{30} \left[1 + \frac{(1)(1)}{30} /2205\right]$$

$$= 0.149 \text{ Mg/yr}$$

$$L_r = ((6.7)(30))(0.0515)(165.82)(1.0)/2205$$

$$= 0.778 \text{ Mg/yr}$$

$$L_f = (242)(0.0515)(165.82)(1.0)/2205$$

$$= 0.937 \text{ Mg/yr}$$

$$L_D = ((0.020)(0)(30)^2)(0.0515)(165.82)(1.0)/2205$$

$$= 0 \text{ Mg/yr}$$

$$L_T = 0.149 \text{ Mg/yr} + 0.778 \text{ Mg/yr} + 0.937 \text{ Mg/yr}$$

$$L_T = 1.86 \text{ Mg/yr}$$

A.3 FUGITIVE EMISSIONS - SAMPLE CALCULATIONS

Fugitive emissions were estimated from the number of equipment leak sources (provided by the plant), the percentage of PCE in the stream (provided by the plant), and the emission factors for each type of equipment (from the SOCMI AID). The following sample calculations illustrate the procedure.

Source	Number		% PCE Service		kg/hr/source Emission Factor[a]		Total Emissions kg/hr
Pump seals	3	x	7.5	x	0.0494	=	0.011
	6	x	50.5	x	0.0494	=	0.150
	2	x	87.5	x	0.0494	=	0.086
	12	x	100.0	x	0.0494	=	0.593
Compressors	1	x	87.5	x	0.228	=	0.200
Flanges	4	x	5.0	x	0.00083	=	0.0002
	112	x	7.5	x	0.00083	=	0.007
	30	x	18.0	x	0.00083	=	0.004
	235	x	50.5	x	0.00083	=	0.099
	66	x	87.5	x	0.00083	=	0.048
	456	x	100.0	x	0.00083	=	0.378

Valves (gas)	4	x	5.0	x	0.0056	=	0.001
	8	x	7.5	x	0.0056	=	0.003
	3	x	50.5	x	0.0056	=	0.008
	4	x	87.5	x	0.0056	=	0.020
	11	x	100.0	x	0.0056	=	0.062
Valves (liquid)	5	x	5.0	x	0.0071	=	0.002
	3	x	7.5	x	0.0071	=	0.002
	8	x	87.5	x	0.0071	=	0.050
	9	x	100.0	x	0.0071	=	0.064
Pressure Relief Devices	2	x	5.0	x	0.1042	=	0.01
	4	x	50.5	x	0.1042	=	0.21
	6	x	100.0	x	0.1042	=	0.63
Sampling Connections	5	x	5.0	x	0.0150	=	0.004
	3	x	50.5	x	0.0150	=	0.023
	1	x	87.5	x	0.0150	=	0.013
	3	x	100.0	x	0.0150	=	0.045
Open Ended Lines	1	x	100.0	x	0.0017	=	0.002
					TOTAL	=	2.7252

$$\text{Annual Emissions} = 2.72\ \text{kg/hr} \times 8760\ \frac{\text{hrs}}{\text{year}} \times \frac{\text{Mg}}{1{,}000\ \text{kg}}$$

$$= 23.87\ \text{Mg}$$

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[a] U. S. Environmental Protection Agency. Fugitive Emission Sources of Organic Compounds - Additional Information on Emissions, Emission Reductions, and Costs. Research Triangle Park, NC. Publication No. EPA-450/3-82-010. April 1982.

APPENDIX B

SUMMARY OF EXISTING STATE AND FEDERAL REGULATIONS AFFECTING PERCHLOROETHYLENE EMISSION SOURCES

B.1 EXISTING STATE REGULATIONS

B.1.1 Introduction

PCE emissions originate at various industrial and commercial sources. These sources include producers of PCE, sources that use PCE either as a dry cleaning solvent, a degreasing solvent, or a chemical intermediate, and sources that store PCE. These emissions can be characterized as either process, process fugitive, or product storage tank emissions.

There are a number of different regulations at the State level that limit PCE emissions. PCE emissions in nonattainment areas (areas that have not achieved the ambient air quality standards for ozone) are normally controlled by the States' RACT program. PCE emissions in areas designated as attainment or unclassified for ozone are controlled by Prevention of Significant Deterioration (PSD) regulations. In addition to the RACT and PSD programs, 12 States (including the District of Columbia) have general VOC regulations that limit emissions of photochemically reactive compounds.

B.1.2 General State VOC Regulations for Solvent Use

Table B-1 presents a list of the States that have adopted a general VOC solvent usage regulation and the emission limits established by each State. These regulations affect volatile organic solvents found to be photochemically reactive and usually require 85 percent reduction in VOC emissions. Sources emitting PCE are currently covered by these regulations.

B.1.3 State RACT Regulations Affecting Perchloroethylene-Emitting Sources

Control Techniques Guideline Documents (CTG) have been issued by EPA for the following PCE emission sources: (1) PCE dry-cleaners; (2) solvent metal cleaners; and (3) SOCMI fugitive emissions. These documents establish RACT guidelines to be used by State agencies in the development of SIP's. Table B-2 presents a summarization of the State RACT regulations for each source category that may emit PCE. While RACT is normally adopted only for nonattainment zones, some States adopt it statewide. RACT has been adopted statewide in Alabama; California; Connecticut; Washington, D. C.; Georgia; Louisiana; Massachusetts; New Hampshire; New Jersey; Ohio; Rhode Island; and South Carolina.

TABLE B-1. GENERAL STATE VOC REGULATIONS FOR PHOTOCHEMICAL SOLVENTS

State	Emission Reduction (%)
California	85
Colorado	85
Connecticut	85
District of Columbia	85
Illinois	85
Indiana	85
Louisiana	90
Maryland	85[1]
North Carolina	85
North Dakota	85
Rhode Island	85[2]
Virginia	85

[1] Applies to sources in nonattainment areas only

[2] Applies to sources emitting less than 100 tons/year, larger sources must comply with RACT

TABLE B-2. STATE RACT REGULATIONS FOR PERCHLOROETHYLENE EMISSIONS

Source Category	State	RACT Provisions
Solvent Metal Cleaning[1]	CT, IN, LA, NV, NH	50% Reduction - Cold Cleaners 45% Reduction - Open Top Vapor Degreasers 25% Reduction - Conveyorized Degreasers
	AL, AZ, CA, CO, DE, DC, FL, GA, IL, KY, MD, MA, MI, MO, NJ, NY, NC, OH, OR, PA RI, SC, TN, TX, UT, VA, WA, WI	65% Reduction - Cold Cleaners 60% Reduction - Open Top Vapor Degreasers 60% Reduction - Conveyorized Degreasers
	AK, AR, HI, ID, IA, KS, ME, MN, MS, MT, NE, NM, ND, OK, SD, VT, WV, WY	Have not adoped RACT regulations for solvent metal cleaning
Perchloroethylene Dry Cleaning	CA, CO, CT, DE, FL, IL, IN, KY, LA, MD, MA, MI, MO, NJ, NC, OH, OR, PA, TN, TX, UT, VA, WA	<100 ppm - dryer Filter Residue <25 lbs solvent Still Residue <60 lbs liquid waste Filters drained in housing 24 hours or longer
	NY	Pending
	AL, AK, AZ, AR DC, GA, HI, ID IA, KS, ME, MN MS, MT, NE, NV NH, NM, ND, OK RI, SC, SD, VT WV, WI, WY	No Regulation
SOCMI Fugitive Emissions	-	CTG Issued, No Regulations Adopted by States
VOL Storage	-	No CTG Issued

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[1] Percent reduction for solvent metal cleaning is estimated, CTG specifies equipment/work practice as RACT.

Emissions of PCE also originate at storage tanks. A CTG for storage of volatile organic liquids is currently under development by EPA but has not been issued.

B.1.4 Prevention of Significant Deterioration Regulations

PSD regulations control VOC emissions from major sources in areas classified as attainment for ozone. Under PSD regulations, a source must seek a PSD permit if it is: (1) a new source with emissions or potential emissions considered major; (2) a major increase in emissions or potential emissions at an existing minor source; or (3) a significant increase in emissions or potential emissions at an existing major source. Emission control levels for PSD are established during the State's review of the PSD permit application prepared for the emission source. Table B-3 presents the emission levels that determine PSD applicability.

B.1.5 State Regulations Affecting Chemical Production

In addition to the general discussion of State regulations concerning PCE emission sources, a more indepth review was performed for States in which PCE production facilities are located. These findings are presented in Table B-4. While PCE emissions are not controlled under these regulations due to the 1.5 psia vapor pressure cutoff, other VOC emissions at these facilities may be.

B.2 EXISTING FEDERAL REGULATIONS

Several VOC NSPS and a NESHAP have been developed that could affect new and some existing sources of PCE emissions. A summary and the current status of each of these standards are presented in Table B-5.

TABLE B-3. PSD APPLICABILITY FOR PERCHLOROETHYLENE EMISSIONS (TONS/YEAR)

Source Category	New Major Source Emissions	Minor Source Emission Increase By Modification	Major Source Emission Increase By Modification
Chemical Production Plants	100	100	40
Dry-Cleaning Facilities	250	250	40
Solvent Degreasing Facilities	250	250	40

TABLE B-4. STATE REGULATIONS AFFECTING CHEMICAL PRODUCTION FACILITIES

State	Source	Regulation
California[1]	Storage tanks >260 gal ≤40,000 gal; Vapor pressure >1.5 psia ≤11.0 psia	Submerged fill pipe or equivalent vapor loss control device
	Storage tanks >40,000	- Pressure tank or - Floating roof with primary & secondary seals - Internal floating roof with primary & secondary seals - Vapor Recovery System with 95 percent recovery
	Process vessel depressurization (precursor organic compound emissions)	After passing though knock-out pot to remove the condensable fraction, the organic compounds must either be: - Recovered & combusted - Incinerated - Flared - Contained & treated
	Valves & flanges (precursor organic compound leaks exceeding 10,000 ppm above background and ≥1.5 psia vapor pressure)	Non-essential valves or flanges repair within 15 days Essential valves or flanges minimize within 15 days
Kansas	No regulations for control of VOC emissions from chemical production facilities	
Louisiana[2]	Storage tanks >40,000 gal Vapor pressure ≤11.0 psia and ≥1.5 psia.	- Pressure tank or - An internal floating roof with a closure seal & submerged fill pipe - An external floating roof with secondary seal and submerged fill pipe - A vapor loss control system & submerged fill pipe

TABLE B-4. (Continued)

State	Source	Regulation
Louisiana (cont.)	Storage tanks >250 gal ≤40,000 gal	- Submerged fill pipe with vapor recovery system
	VOC loading facilities servicing tanks, trucks or trailers having a capacity of >200 gal & throughput ≥20,000 gal/day (40,000 gal/day for existing facilities)	- Vapor collection & disposal system
	Pumps, compressors, valves, etc. (≥1.5 psia vapor pressure compounds)	Equipped with mechanical seals & maintained to prevent leaks
	Waste gas disposal containing organic compounds from any emission source including process unit upsets, start-ups and shutdowns.	Halogenated hydrocarbons shall be burned & the products of combustion subsequently controlled. Other methods such as carbon adsorption, refrigeration, catalytic/thermal reaction can be substituted. Provisions may be waived if gas stream <100 T/yr, will not support combustion without auxiliary fuel, or control will cause economic hardship
	Facility emitting >1.4 kg/hr or 6.8 kg/day of VOC as solvent	- Must reduce emissions either by incineration (90% removal efficiency) or by carbon adsorption system. During process upsets, start-ups, or shut downs, VOC emissions must be vented and reduced either by an afterburner, carbon adsorption system, refrigeration, catalytic and/or thermal reduction, secondary steam stripping, or vapor recovery system.

TABLE B-4. (Continued)

State	Source	Regulation
Michigan[2]	Storage tanks >40,000 gal true vapor pressure >1.5 <11.0 (existing sources)	- Pressure tank or - Floating cover with closure seal or seals - Vapor recovery system capable of 90 percent recovery
	Storage of organic compounds having a true vapor pressure ≥11 psia in existing vessels of >40,000 gallons	- Pressure tank capable of maintaining working pressures sufficient to prevent organic vapor or gas loss to atmosphere - Vapor recovery system which recovers >90% by weight of uncontrolled organic vapor - All openings shall be equipped with covers, lids, or seals
	VOC loading facilities handling ≥5,000,000 gal/year of >1.5 psia VOC	- Submerged fill pipes in ozone attainment areas
Texas[2]	Storage tanks vapor pressure ≥1.5 psia, <11 psia	
	≤1000 gal	- None
	>1000 gal <25,000 gal	- Submerged fill pipe
	>25,000 gal ≥42,000 gal	- Internal or external floating roof with primary & secondary seal, or vapor recovery system
	VOC loading and unloading facilities with >20,000 gal/day throughput of ≥1.5 psia VOC	Vapor recovery system
	Vent gas control (≥0.4 psia vapor pressure)	Flared or incinerated at 1300°F

TABLE B-4. (Concluded)

State	Source	Regulation
Texas (cont.)	SOCMI Fugitive VOC (Harris County)	No compound shall be allowed to leak with a VOC concentration >10,000 ppm (time limits given
	Storage tanks containing vinyl chloride	Concentration of exhaust gases discharged to the atmosphere from storage tanks must not exceed 10 ppm (NESHAP - Vinyl Chloride)

[1] Bay Area Air Quality Management District Rules and Regulations. San Francisco, CA.

[2] Environment Reporter, State Air Laws. Washington, D.C. Bureau of National Affairs.

TABLE B-5. SUMMARY OF FEDERAL REGULATIONS AFFECTING PERCHLOROETHYLENE EMITTING SOURCES

Source	Proposed	Promulgated
Degreasers (Organic Solvent Cleaners) NSPS	06/11/80 (applicability date deferred)	
SOCMI Equipment Leaks (Fugitive) NSPS	01/05/81	10/18/83
VOL Storage Vessels NSPS	10/84	
SOCMI Air Oxidation NSPS	10/21/83	
SOCMI Distillation Operations NSPS	12/30/83	
SOCMI Reactor Processes NSPS	04/85	
Vinyl Chloride Manufacturing NESHAP	12/24/75	10/21/76

APPENDIX C

MATERIAL BALANCE FOR PCE EMISSIONS FROM DEGREASING OPERATIONS

APPENDIX C: MATERIAL BALANCE FOR PCE EMISSIONS FROM DEGREASING OPERATIONS

C.1 MATERIAL BALANCE

(1) - Fraction of degreasing use of PCE in cold cleaning = 0.24

Fraction of degreasing use of PCE in vapor degreasing = 0.76

- Emission factors:

- cold cleaning:	0.43 kg/kg used
- open top degreasing:	0.78 kg/kg used
- conveyorized degreasing:	0.85 kg/kg used

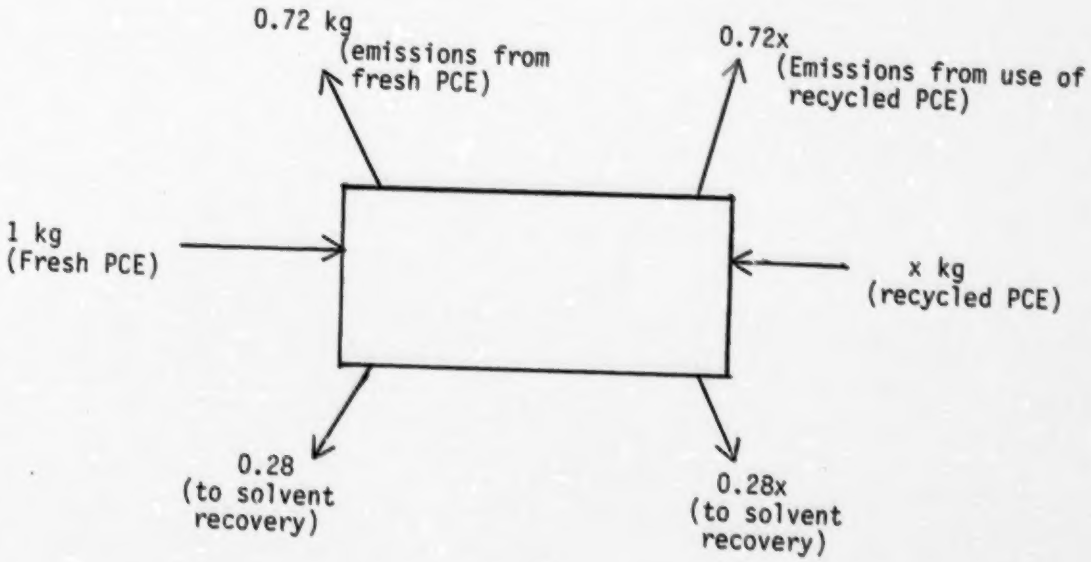
- Assuming vapor degreasing is divided equally between open top and conveyorized vapor degreasing, a weighted average emission factor is calculated as follows:

$$(0.24)(0.43) + (0.38)(0.78) + (0.38)(0.85) = 0.72 \text{ kg/kg used}$$

(2) - For every kg of fresh PCE used, 0.72 kg is emitted. Assume all of the remaining 0.28 kg is sent to solvent recovery.

- Estimate that 75 percent of all solvent sent to recovery is recycled.

- Calculate emissions as follows:


0.72 kg
(emissions from fresh PCE)
0.72x
(Emissions from use of recycled PCE)
1 kg
(Fresh PCE)
x kg
(recycled PCE)
0.28
(to solvent recovery)
0.28x
(to solvent recovery)

$x = 0.75\ (0.28 + 0.28x)$

$x = 0.27$ (Amount of recycled PCE used per kg of fresh PCE used)

$0.72x = 0.20$ (Amount of recycled PCE emitted per kg of fresh PCE used)

Total PCE emitted per kg of fresh PCE used $= 0.72 + 0.20$

$= 0.92$ kg

APPENDIX D

PERCHLOROETHYLENE EMISSIONS FROM DISTRIBUTION FACILITIES

D-1 PERCHLOROETHYLENE EMISSIONS FROM DISTRIBUTION FACILITIES

1) Estimate the quantity going through distribution (storage)

1983 production = 509 MMlbs

Assume 70 percent goes through distribution channels

(509 MMlbs)(0.70) = 356 MMlbs

2) Estimate the number of storage tanks nationwide

- Assume the average tank size is 8,000 gallons
- Assume the average turnover time is 1 month

$$\text{Number of tanks} = 356\ \text{MMlbs}\left(\frac{\text{gal}}{13.5\text{lb}}\right)\left(\frac{1\ \text{tank}}{8{,}000\ \text{gal X }12}\right) = 270\ \text{tanks}$$

3) Estimate storage emissions (fixed roof tanks)

Breathing Loss

$$L_B = 1.02 \times 10^{-5}\, M_V \left(\frac{P}{14.7-P}\right)^{0.68} D^{1.73}\, H^{0.51}\, T^{0.5}\, F_P\, CK_c$$

$$L_B = 1.02 \text{ X } 10^{-5}\,(166)\left(\frac{0.5}{14.7-0.5}\right)^{0.68}\,(10)^{1.73}\,(7)^{0.51}\,(1.15)(0.5)(1.0)$$

$$L_B = 0.014\ \text{Mg/yr}$$

Working Loss

$$L_W = 1.09 \times 10^{-8}\, M_V P V N K_n K_c$$

$$L_W = 1.09 \text{ X } 10^{-8}\,(166)(0.5)(8{,}000)(12)(1)(1)$$

$$L_W = 0.087\ \text{Mg/yr}$$

Total Loss

$$L_T = L_B + L_W = 0.10\ \text{Mg/yr per tank}$$

Total nationwide storage emissions = (0.10)(270) = 27 Mg/yr

where:
M_v = molecular weight of product vapor (lb/lb mole)
P = true vapor pressure of product (psia)
D = tank diameter (ft)
H = average vapor space height (ft)
T = average diurnal temperature change (°F)
F_p = paint factor (dimensionless); 1.0 for clean white paint
C = tank diameter factor (dimensionless):
  for diameter $\geq$ 30 feet, $C = 1$
  for diameter $<$ 30 feet, $C = 0.771D - 0.013D^2 - 0.1334$
K_c = product factor (dimensionless) = 1.0 for VOL
V = tank capacity (gal)
K_n = turnover factor (dimesionless):
  for turnovers > 36, $K_n = \frac{180 + N}{6N}$
  for turnovers $\leq$ 36, $K_n = 1$

4) Estimate container filling emissions

Loading Loss

$$L_L = 12.46 \frac{S\ T\ P}{R}$$

where: S = Saturation factor (0.50 for submerged fill and 1.45 for splash fill)
P = True vapor pressure, psia
M = Molecular weight
T = Temperature, °R

Assume 50 percent splash filling (S = 1.0)

$$L_L = 12.46\left(\frac{(1.0)(0.5)(166)}{530}\right) = 1.95\ \text{lb}/10^3\ \text{gal}$$

$$= 0.89\ \text{lb}/10^3\ \text{gal}$$

$$356\ \text{MMlb}\left(\frac{\text{gal}}{13.5\ \text{lb}}\right)\left(\frac{0.89\ \text{kg}}{10^3\ \text{gal}}\right) = 23\ \text{Mg/yr}$$